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RAPID TRANSIT SUBWAYS - MAINTENANCE GUIDELINES

James Birkmyer

Bechtel Incorporated
Fifty Beale Street
San Francisco CA 94119

JANUARY 1978
GUIDELINES

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16. Abstract

Several kinds of maintenance are required in a subway complex, including inspective, scheduled and nonscheduled maintenance as well as repairs.

Stations are cleaned daily and washed periodically. Trackways are cleaned with track mounted equipment.

Variables existing among transit properties — including age, size, train schedules, geology, and type of structures — largely determine maintenance practices. Structural maintenance includes repair of concrete and steel items and stoppage of water seepage, activities that require special details, materials, and installation techniques. Severe leakage can be stopped by grouting the soil surrounding the structure. Adequate soils data and expert advice on grouting systems are needed to determine correct grouting procedures.

To function reliably, drainage systems may require much effort to prevent clogging.

Mechanical and electrical equipment comprising escalators, elevators, pumps, and ventilation fans requires regular lubrication and adjustment of components and controls. This maintenance is intensive for escalators and elevators with longer term major overhauls.

Repair or replacement of architectural finishes involves numerous materials and items as well as expert installation techniques for satisfactory results.

Station cleaning is labor intensive, and economy requires that procedures be systemized and frequently monitored. The use of mechanical sweepers and washers should be analyzed for optimization with labor costs.

Sensitive train control equipment requires periodic removal of metallic and other dust from the trackways. Suitable rail-mounted cleaning equipment, either vacuum or wash, should be carefully selected.

Maintenance organization and operations require effort in three areas: management, direction, and coordination; engineering, inspection, planning design, and scheduling; and field forces to perform maintenance and cleaning.

Experienced maintenance engineers should review and analyze all maintenance procedures frequently, modifying and upgrading them as necessary to maximize efficiency.

Appropriate workshops, staff facilities, and storerooms are needed for the various trades, materials, components, and equipment required in the maintenance process.

Scheduling, transportation, and accesses are all constrained by the types of maintenance involved, location of the work, and the revenue service schedule, all of which must be reconciled in determining individual maintenance schedules.

Guidelines and justification for good maintenance practices are presented.

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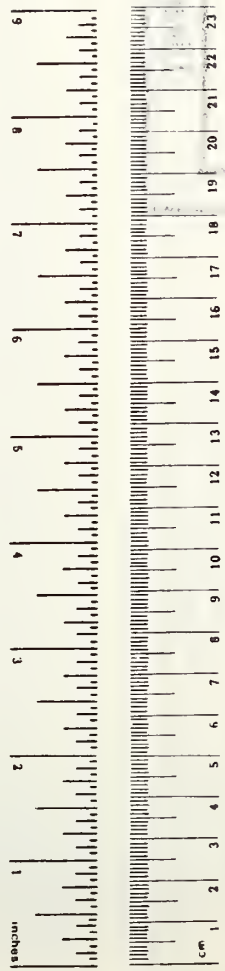
METRIC CONVERSION FACTORS

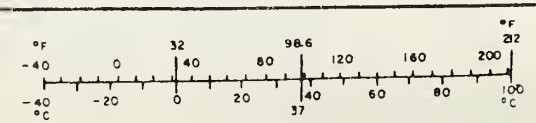
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	squere meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	qwerts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yerds	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	squere yerds	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	ecres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

The objective of these guidelines is to develop maintenance procedures for underground transit structures. The guidelines are largely a distillation of maintenance data obtained from transit properties visited in this country and abroad, whose systems vary greatly in design, type of construction, age, and capacity. Consequently, the organization and maintenance practices vary considerably from one property to another, and the guidelines must be viewed with these limitations in mind.

In these guidelines, and in those for new properties, cost analyses are recommended for evaluating tradeoffs between capital expenditures and maintenance expenses. Correct maintenance procedures have been found to represent good economics.

Improving and upgrading existing systems is challenging and requires long range planning. The ultimate goals must be defined and a program developed to meet these goals. Generally speaking, existing facilities and maintenance procedures are evaluated and, where necessary, alterations or improvements are made to attain the goals. New maintenance standards are developed, work schedules prepared, and staff trained to meet the new challenge.

The design staff of a new system should include the engineer responsible for its maintenance and cleanliness. During the construction stage, the maintenance engineer should develop work methods and schedules and determine staff requirements, so that a fully operational maintenance force will be available when the system opens. Key maintenance staff

can be sucessfully trained by serving as inspectors or participating in acceptance and approval of their respective facilities.

Above all, a maintenance force for both new and existing systems must have a pride of workmanship, be proud of their contribution, and have a sense of belonging to and being one of the best. Only dedicated leadership and a committed management can make this happen.

It is sincerely hoped that these guidelines can assist in keeping rapid transit systems a viable alternative for moving people within our cities.

The sponsor of this study was The Office of Rail Technology, Office of Technology Development and Deployment, Urban Mass Transportation Administration. It is part of the Coordinated Department of Transportation Tunneling Program.

This work was performed under contract to the Transportation Systems Center (TSC), Cambridge, Mass. The contract was awarded under TSCs Urban Rail Supporting Technology Program with Mr. Gerald R. Saulnier of the Office of Ground Systems as technical monitor. The author wishes to thank UMTA, the sponsor, and Mr. G. Saulnier of TSC, for the assistance and advice provided during the execution of the work.

Early in the work schedule, the American Public Transit Association (APTA) formed a Maintenance Guideline Committee, the members of which comprised the Maintenance Superintendents of Massachusetts Bay Transportation Authority, Chicago Transit Authority, New York City Transit Authority, New York Port Authority Trans-Hudson Corporation, and Washington Metropolitan Area Transit Authority. Under the Chairmanship of TDC, the committee defined maintenance areas of particular interest to ongoing operating properties. The committee also provided

considerable maintenance data from represented properties and valuable constructive critiques of the Guidelines as they were being written.

Bechtel's consultants for the work were Mr. E. E. McPhail, Manager of Plant Maintenance, Toronto Transit Commission, and the Maintenance Superintendents of the London Transport Executive. Both consultants drew deeply from their considerable experiences in maintaining their subways and greatly assisted in formulating many of the Guidelines.

Other transit property managements who cooperated most helpfully in this work, by making available both their maintenance engineering staff for onsite discussions and by providing their maintenance data, were San Francisco-BART, Paris-RAPT, Stockholm-SL, Brussels-STIB, Berlin-BVG, Hamburg-HHA, and Munich-SV.

Several maintenance equipment manufacturers and contractors provided useful data about their particular equipment or operations. These included the San Francisco offices of Otis Elevator Company, Easterday Supply Corporation, Clarke-Gravely Corporation, American Colloid Company, and American Building Maintenance Company.

For the assistance provided by these transit properties, organizations, and manufacturers, the author wishes to extend his thanks and especially to the various staff who, in spite of busy work schedules, gave their time freely to provide the information sought.

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Section 1

SUMMARY

A considerable amount of detailed maintenance information was obtained from both overseas and North American transit properties and synthesized to compile these guidelines. Most of the properties differ fundamentally in regard to age, size and capacity, operating schedules, construction systems and details, rolling stock used, and several other aspects. These differences made it difficult to synthesize the material to allow evaluation on common bases; however, in spite of the differences in actual systems, a heartening unanimity was found among the engineers in charge of maintenance toward setting high goals for maintaining their subway properties. In most cases, these goals aimed at achieving overall or long-term economies, and these philosophies have influenced the formulation of the guidelines.

SECTION 2 – TYPES OF MAINTENANCE

Several types of maintenance are required to keep the items within a subway complex in satisfactory condition. The items are: structures, station finishes (including floors, walls, ceilings, doors, etc.), escalators and elevators, fans, pumps, and lights.

The main types of maintenance are:

- Inspective. Comprises frequent general inspection and periodic inspection at longer intervals and more detailed in nature. Both monitor the condition of the maintainable items and establish the necessary maintenance and procedures to keep these items in satisfactory condition.

- Scheduled Preventive. Includes all foreseeable maintenance ideally required to maximize the service life of an item and replacement of components (or the items themselves) when needed. This work is undertaken within scheduled programs.
- Nonscheduled Maintenance and Repairs. Generally comprise repair occasioned by breakdown or accidental damage.
- Cleaning – Short-term and Long-term. The former relates to almost continuous removal of debris from the stations during revenue service; the latter includes both station and trackway cleaning or washing and debris removal from pump sumps, fan and other shafts, equipment rooms, and drainage. All this is performed at regularly scheduled periods.

SECTION 3 – MAINTENANCE PROCEDURES AND DETAILS

Guidelines are provided for several types of maintenance procedures (as defined in Section 2) for items in the subway complex. The numerous physical and other differences among transit properties are identified and, to qualify the use of the guidelines, the effects upon maintenance requirements are listed, briefly described, and indicated by interaction diagrams.

For structure maintenance, guideline recommendations are made for the base data that must be assembled for the design and initiation of the maintenance work. These data included geological conditions, design data and records, and construction history.

The guidelines include:

- Inspection and monitoring of defects that generally develop in the several types of structures used in underground construction,
- Repair of cracked or otherwise defective concrete and expansion and other joints,

- Where soil grouting may be an expedient method of stopping water ingress in a structure, guidance is provided for the formulation of such a program, and
- Additional items covered include the repair of and protection from corrosion of exposed steel work repair of leaks or, alternatively, channelizing water in segmented lined tunnels.

Maintenance of mechanical and electrical equipment is a well established procedure, and the methods are tailored to the particular requirements of actual equipment installed in a transit property.

Because many materials are used and great variations of service are imposed on them, the guidelines for architectural station finishes emphasize and provide examples of recording forms suitable for identifying types and causes of damage. Recording of the remedial measures adopted to allow historical monitoring of the success or failure of remedial measures is also described. The guidelines include the repair of various materials, applications, and systems for walls, floors, ceilings, and doors.

SECTION 4 – JANITORIAL SHORT- AND LONG-TERM CLEANING

The procedures for formulating station cleaning programs are described, and a task flow chart is presented that indicates the various subjects of the guidelines. The items are grouped under three general heads: data requirements, methods and schedules, and organizations.

Both manual and mechanized cleaning methods for stations are discussed, with guidelines provided for both. Recommendations for optimizing the methods are also provided.

The subjects of trash collection and disposal and a "public relations" program to reduce litter are also included.

Trackway cleaning, which is presently a subject of importance to many transit properties, is covered by guidelines under the general heads of "Cleaning Programs" and "Cleaning Methods." The former group is presented by task flow chart, similar in scope to station cleaning. Optimizing the cleaning methods requires evaluation of two major equipment principles: wash and vacuum, and guidelines, are provided for identifying the most economic methods, as well as for selecting combinations of the several types of equipment presently available in the market. Scheduling, a critical aspect of any operation in the trackway, is also covered.

SECTION 5 – MAINTENANCE AND CLEANING ORGANIZATIONS AND OPERATIONS

A discussion preceding the guidelines describes the principal areas of responsibility of a typical maintenance organization. The basic relationships with "train" and "station" operations and the subway (or plant) maintenance group, and with other maintenance groups, "track", "power", etc., are shown in a task flow chart. Details of the engineering and maintenance task forces are also shown and described in the text. Maintenance group organizations for alternative "centralized" or "area" system approaches are indicated and described.

The guidelines recommend the types of personnel required for directing the maintenance and cleaning operations. Approaches for determining the most economic maintenance systems are also covered.

SECTION 6 – EQUIPMENT, SUPPLIES, AND FACILITIES

The equipment commonly used in the repair and maintenance of trackway and station structures and architectural finishes, trackway and wayside facility cleaning, and mechanized station cleaning are listed, and guidelines are provided to aid in the selection of appropriate equipment for the work and conditions.

Checklists are also compiled for materials (including consumables) and parts required for the items in the various maintenance areas, and guidelines cover the determination and maintenance of the stock at satisfactory levels.

The support facilities for the maintenance operations include provision for storage of material and equipment both within the stations and in off-site warehouses and shops. Guidelines cover considerations for providing the necessary facilities, which are indicated in typical layouts.

SECTION 7 – SCHEDULING TRANSPORTATION AND ACCESS

The interrelationships of scheduling, transportation, and access for the maintenance of items within the subway complex with other maintenance operations and with the train revenue service schedule are identified and discussed.

The related guidelines are oriented to these matters including:

- Categorizing maintenance activities by their physical location. The effect upon transportation is indicated in tabular form for item location in trackway and wayside structures and in stations.
- Detailed maintenance schedules showing typical forms for scheduling work in the three locations are indicated.
- Transportation vehicles for labor, equipment, and materials between shops, stores, and depots to the places of work. Rail-mounted vehicles are included for trackway work, road or rail for stations and other areas.

Section 2

TYPES OF MAINTENANCE

Several distinct types of maintenance are required in every subway property; the types vary according to the particular operation required, the timing, and the equipment involved. These types of maintenance will be defined accordingly and, to avoid confusion, various maintenance actions will either be qualified or given separate terminology. In general, frequent removal of dust and debris from station floors is called "short-term cleaning;" washing (or otherwise cleaning) station floors, walls, ceilings, etc., is called "long-term cleaning" and is undertaken at longer intervals than is the short-term work. Removing dust and other material from the trackway by washing or by other means is also classified as either short- or long-term cleaning.

INSPECTION FOR MAINTENANCE

Inspection for maintenance requirements establishes the need for the type of maintenance appropriate to specific areas. The inspection operation is performed either visually or with the aid of inspection instruments and equipment. The major elements of a subway installation are listed in the following paragraphs together with the recommended inspection for them.

Structures:

Maintenance inspection for structures should include the following activities:

- Frequent general inspection, by trackwalkers and the maintenance section, of trackway structures for obvious defects including clogged or stopped drainage, and

- Periodic (typically annual) inspection of trackway and appurtenant structures and station structures at a frequency dependent on condition and type of structure. This inspection should be performed by the structures section who will record defects and program their repair.

Station Finishes:

The finish or surface of stations should have the following attention:

- Daily general inspection, by station and cleaning staffs, for breakage of vulnerable items such as wall paneling, glass lights, etc.
- Periodic detailed checks of the items listed in the preceding bullet by the building or structures section.
- Periodic (typically annual or semiannual) detailed inspection, by the building or structures section, resulting in inventories of defective items and programs for their repair or replacement.

Escalators and Elevators:

Escalators and elevators will require frequent inspection (sometimes daily) to assure that electrical control equipment and mechanical components are functioning properly.

Fans and Pumps:

The electrical systems controlling fans and pumps as well as the mechanical components should be inspected periodically (typically monthly) by the electrical mechanical sections.

Lights:

Frequency of inspection depends on replacement method. Periodic total replacement requires much less inspection than a program of individual replacement as bulbs burn out.

SCHEDULED AND PREVENTIVE MAINTENANCE

Scheduled and preventive maintenance should be performed according to predetermined schedules. Some recommendations are presented in the following paragraphs for the major areas of subway properties.

Structures:

Depending on the type and condition of the structures, repair and replacement may be on a continuous programmed basis in the trackway structures. This is appropriate because of the short time during which work areas can be occupied.

Station Finishes:

For certain heavy wear items such as floors and stairs, replacement may be a continuous programmed operation. Wall and ceiling replacements are generally intermittent processes (several or many years between replacements).

Escalators and Elevators:

At regular and relatively frequent intervals, these items require maintenance that includes adjusting electrical controls, greasing, etc. Major overhauls that may involve replacement of parts, ropes, chains, etc. are typically programmed for one- to five-year intervals.

Fans and Pumps:

Fans and pumps require maintenance similar to that for escalators and elevators except that the intervals are normally longer.

Lights:

If replacement is on a "burn out" basis, replacement may be undertaken at short intervals (two to three days). If lamp replacement is on a "total"

basis, replacement may be undertaken on a yearly basis for fluorescent lamps and more frequently, perhaps on a three-month basis, for incandescent lamps. Normally, this work is done by the electrical section.

NONSCHEDULED MAINTENANCE AND REPAIRS

These activities are occasioned by the following unavoidable but unschedulable emergencies:

- Breakdown of mechanical and electrical equipment,
- Blocking of drainage system,
- Rolling stock accidents resulting in structure leaks, cracks, and damage, and
- Station damage such as broken glass, damaged doors, loose floor tiles, vandalized walls, defacements, etc.

SCHEDULED SHORT-TERM MAINTENANCE AND CLEANING

Most short-term maintenance will take place in stations and will include policing floors for debris accumulation and checking walls for defacements and other damage. This is often undertaken two or three times each rush hour in busy stations and twice daily in stations with light patronage. Debris may be removed, by sweeping and spot cleaning, on a daily or more frequent basis. Electrical and mechanical equipment will also be inspected frequently.

SCHEDULED LONG-TERM MAINTENANCE AND CLEANING

Long-term maintenance normally will include the following activities:

- Cleaning of structures and performing required maintenance,
- Cleaning of station finishes and performing required maintenance,
- Cleaning trackway with track-mounted washing or vacuum equipment (sometimes this job is undertaken manually),
- Thorough cleaning (usually by washing) of station walls and ceilings,

- Cleaning of lamp and light fixtures,
- Removing dust and debris from ventilation shafts, emergency exits, escalators, and elevators, and
- Removing and cleaning pump sumps and drainage systems.

Section 3

MAINTENANCE PROCEDURES AND DETAILS

This section provides guidelines for performing various types of maintenance needed to keep an underground transit structure and its related finishes and equipment in satisfactory condition. As discussed in Section 2, maintenance procedures and details depend on numerous variables that exist among the different systems, and many cases may be unique for a particular transit property. Often these variables exercise constraints on or will determine special maintenance procedures. Therefore, before the maintenance guidelines set forth here are adopted for any particular transit system, their applicability must be measured against the variables of the system.

The scope includes maintenance, repair, or replacement of structures, station finishes, escalators and elevators, fans and pumps, and lights. For each item covered, maintenance requirements will be stated, procedures and details for maintenance will be recommended, and the recommendations will be justified.

Structural maintenance is covered in Guidelines 3-1 through 3-20, mechanical and electrical equipment in Guidelines 3-21 through 3-43, and architectural finishes in Guidelines 3-44 through 3-48.

INTERACTION OF VARIABLES

The major variables within a transit system have been grouped and categorized in Figure 3-1.

Maintenance factors have been subdivided into six groups lettered A through F. The variables, constraints, and dirt and dust generants itemized in A, C, and E affect one or another of the maintainable items listed in B and F and, consequently, the maintenance organizations and operations in D.

Group A consists of two sets of major variables. The first are considered fundamental and concern the age, size, geographic location, and train schedule (or intensity of train service) of a transit system. All variables except geography have a profound effect on the maintenance organization and operations.

Group B comprises the maintainable trackway items, the trackway structure, and the station structure. Group C includes items that can constrain the maintenance operations and items or occurrences that generate maintenance. Group C affects Group B and the trackway cleaning system.

Group D comprises two categories – "Maintenance Organization" and "Maintenance Operations" – that interact with each other and with the maintainable items. Trackway and station constraints will also affect some of the items in Group D.

Group E contains two main categories: major constraints to maintenance operations caused by station construction and major generators of maintenance. Group F includes maintainable architectural, mechanical, and electrical items within the station.

To indicate in more detail the complex interactions among design variables, the maintainable items, the maintenance generants and constraints, and the maintenance operations, two figures have been prepared: Figure 3-2

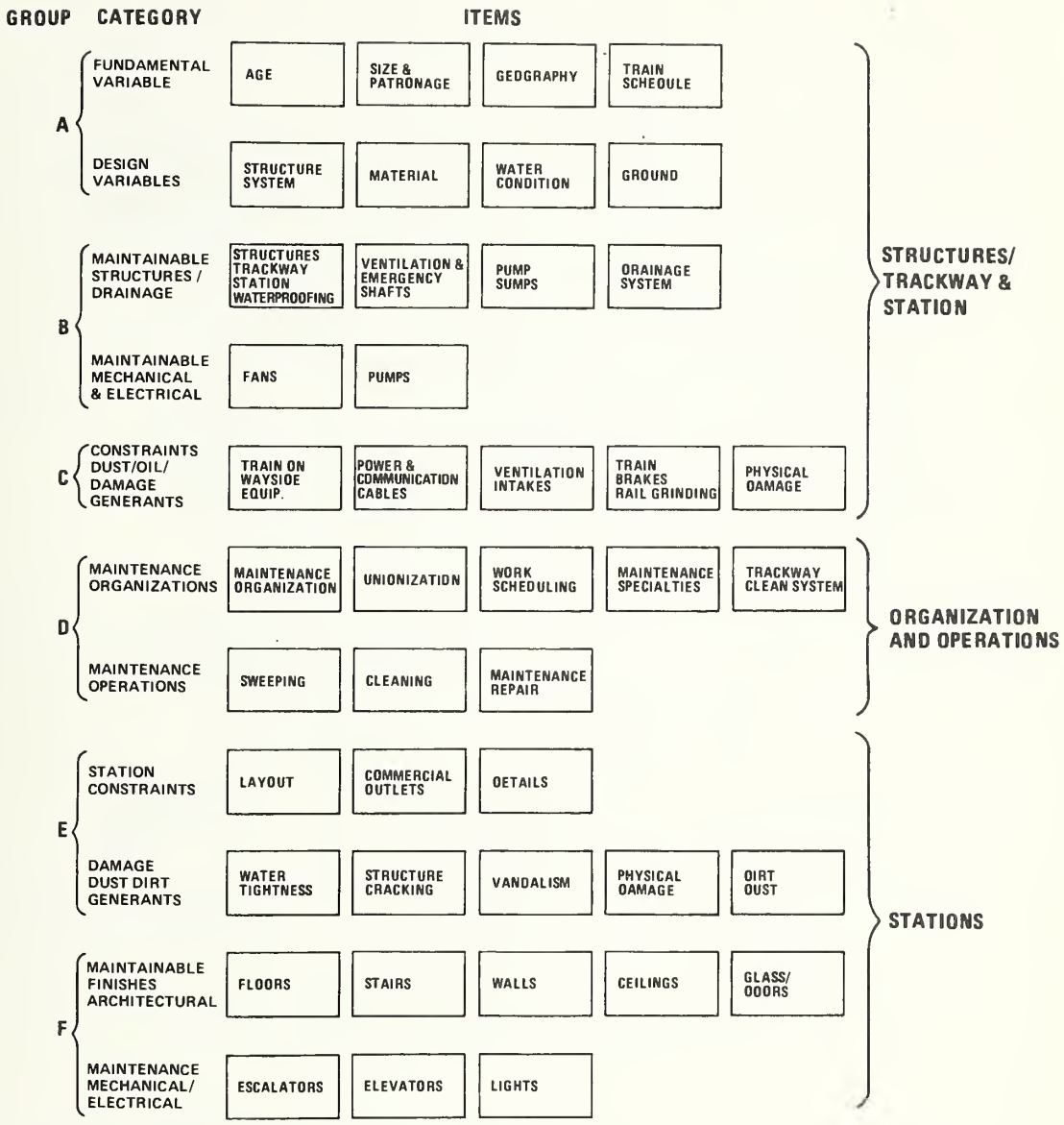


Figure 3-1. INTERACTION DIAGRAM OF VARIABLES (OWNER/OPERATORS GUIDELINES FOR MAINTENANCE OF SUBWAY STRUCTURES)

relating to trackway structures and equipment, and Figure 3-3 relating to stations and equipment.

The importance of interaction among the variables, constraints, and maintenance generators on maintenance organizations and operations becomes apparent after an examination of the guidelines for maintenance and cleaning, which are outlined in the remainder of this section. The guidelines are divided into four chief areas of maintenance concern:

- Structures – cut-and-cover, cast-in-place, and segmented lined tunnels,
- Mechanical and electrical equipment – escalators, elevators, trackway pumps, trackway ventilation equipment, and lights,
- Architectural finishes – floors, walls, and ceilings, and
- Cleaning – short- and long-term cleaning of stations and trackways.

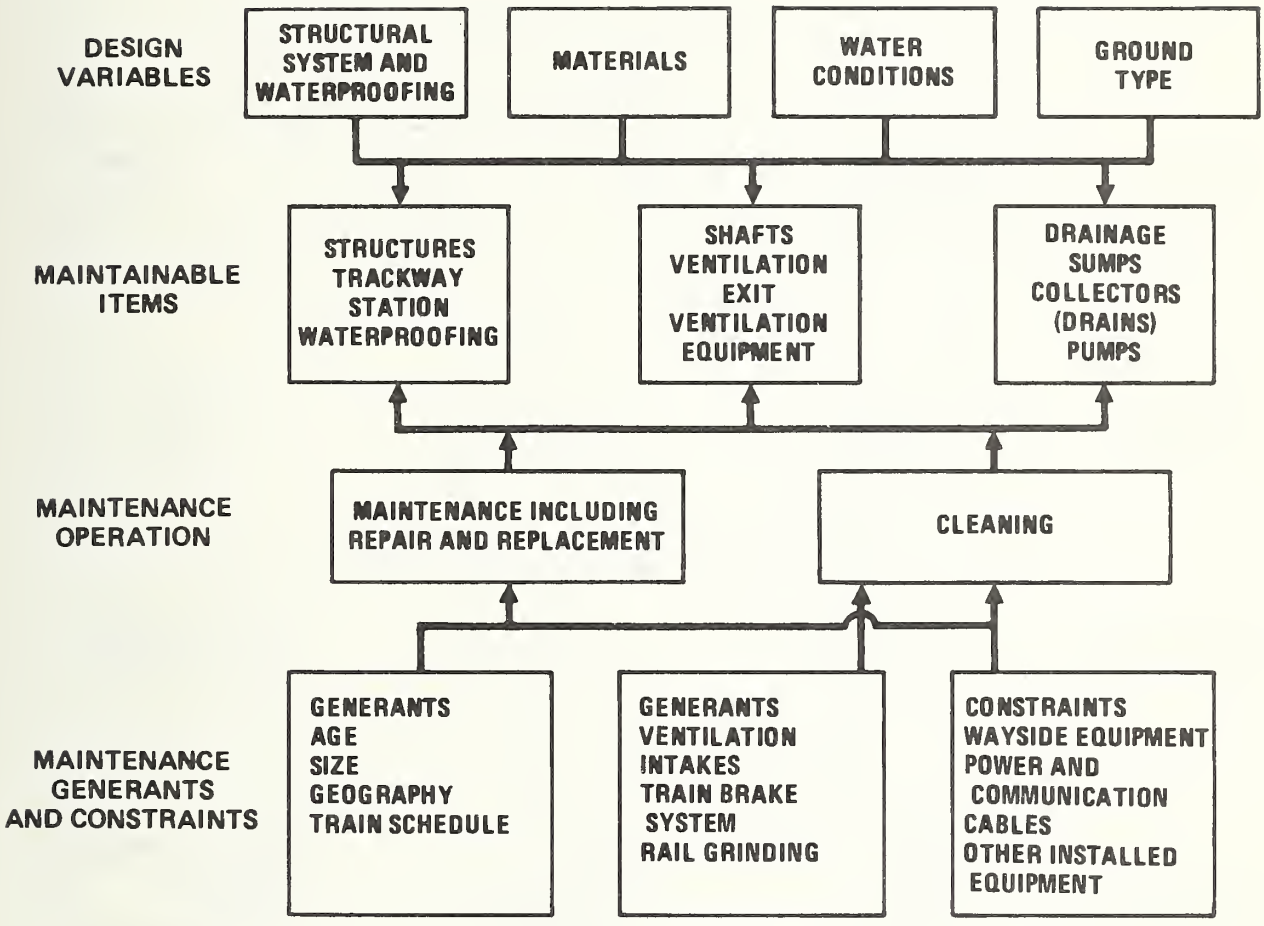


Figure 3-2. INTERACTION OF VARIABLES ON MAINTENANCE AND CLEANING TRACKWAY AND OTHER STRUCTURES AND TRACKWAY EQUIPMENT

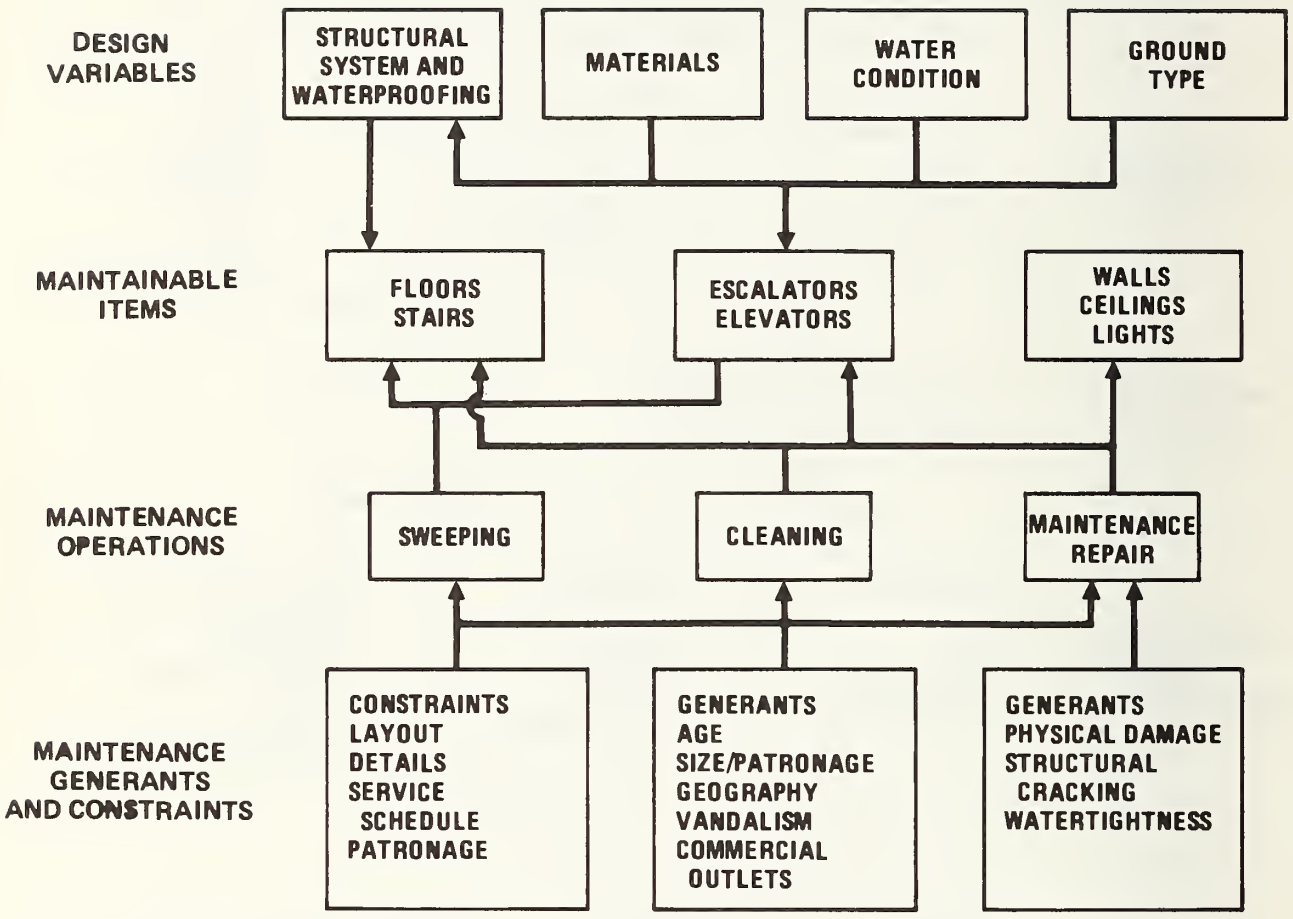


Figure 3-3. INTERACTION OF VARIABLES ON MAINTENANCE AND CLEANING OF STATIONS AND STATION EQUIPMENT

STRUCTURE MAINTENANCE

Maintenance of the underground structures falls into four major areas: concrete work, soil grouting, steelwork, and tunnel liners. Each is covered in the following guidelines.

OVERALL CONSIDERATIONS

Guideline 3-1 – General Data Required

A prerequisite for underground structure maintenance is the assembly of all data relative to the design and construction of the structures. It is recommended that the data include the following components for all sections along the subway route.

Geological. Ground and geological information must be gathered about the following specific areas:

- Natural ground and backfill, including physical and chemical classification, strength, density, and water content,
- Height of the existing groundwater table and the chemical composition of the water, and
- Depth of ground cover over the structures; identification of all surcharging loads, including fills and structures, that have been constructed within a critical vicinity of the underground structure.

Design. The original design and any subsequent modifications must be examined to determine the following:

- Design loadings and stress adopted,
- Design system and philosophy,
- Material specifications including concrete mixes, steel grade strengths, waterproofing systems, and sealants, and
- Design drawings and structure details including expansion, construction, and contraction joints; structural steel seatings; water seals; caulking and bolting systems; and waterproof membrane sealing details.

Construction History. The actual construction records should be investigated to collect the following information:

- As-built drawings and details,
- Records of unanticipated construction problems that could affect structure performance, and
- Deviations from specifications.

Justification:

Possession of the data described in the preceding paragraphs will permit knowledgeable maintenance planning because it provides information that can be used to do the following:

- Provide the basis for recording inspection maintenance information,
- Assist in determining causes and the degree of deflections and cracking,
- Assist in designing corrective measures, and
- Provide essential data for estimating the durability of the structures.

Guideline 3-2 — Structure Inspection for Maintenance

Subway structures should be inspected periodically to establish maintenance requirements. Depending on the type of structure being inspected, the following items and conditions should be recorded.

Cut-and-Cover and Tunnel Structures — Cast-in-Place Concrete. For these types of structures, attention should be paid to the following items:

- Stress cracks and other types of cracks,
- Concrete spalling or other forms of deterioration,
- Leaks through cracks and expansion and construction joints; rust stains from reinforcement,
- Water flow in filter drainage systems,
- Excess movement at expansion joints, and
- Plugging of filter drains.

Built-in steel members should be inspected for the following:

- Corrosion,
- Water seeps between steel and concrete, and
- Buckling.

Tunnel Structures – Shotcrete Lining. Shotcrete is liable to the following troubles:

- Loose (or loosening) aggregate,
- Bonding failure of lining,
- Leakage and water seeps, and
- Rust stains from reinforcement, rock anchors, and steel sets.

Segmented Lined Tunnels. In these types of structures, the components should be checked for various failures.

Precast concrete is subject to the following problems:

- Failure of caulking (waterproofing) and water inflow,
- Cracking, spalling, and rust staining,
- Bolt corrosion,
- Failure of grommets, water inflow, loose bolts.

Cast iron members may have the following problems:

- Caulking and bolt grommet failure allowing leakage,
- Loose bolts,
- Cracked segments, and
- Corrosion.

Fabricated steel members should be checked for the following problems:

- Caulking and bolt grommet failure allowing leakage,
- Loose bolts and sheared rivets,
- Buckled segments, and
- Coating failures and corrosion.

Justification:

Deterioration in underground structures is caused primarily by structure cracking, corrosion of metallic structural parts and reinforcement,

waterproofing failure, disintegration of concrete because of chemical attack, disintegration of waterproofing because of chemical attack, and water seepage. Water seepage may seriously affect the performance of several items within the underground structure; the lighting system, train control equipment, walls, and ceilings. Therefore, systematic inspection and recording of structural conditions are essential for an orderly plan for repair of structural defects.

Guideline 3-3 — Monitoring Structural Defects

Modes of structural deterioration are time dependent: after a period of time they may become static, may self-correct, or may progress. Certain defects must be monitored and conditions or changes reviewed after subsequent inspections. For the items listed in the following paragraphs, explicit monitoring activities are recommended.

Cracks in Concrete. Such cracks should be carefully inspected and ideally treated in the following manner.

- Identify easily visible (1/100-inch or larger) surface cracks as caused by "flexure" or "shrinkage",
- Monitor representative sizable or "suspicious" cracks (1/50-inch or larger) of each class by gluing water-proof "tell-tales" across the cracks,
- Mark cracks boldly and number them to permit easy identification and recording,
- If subsequent inspections indicate increased crack size, insert gauge points across the crack to permit measuring, and
- Record seepage or water inflow quantity as closely as possible.

Justification:

Data about cracks in concrete provide an insight into its structural competence. If flexure cracks continue to increase, they may be caused by

overload, and the dimensions of the crack can aid in estimating stress across the reinforced concrete section. Continuing movement of a shrinkage or flexure crack carrying water will determine the remedial sealing approach.

Distortions or Movements in Structures. Geological formations (rock and soil) are never completely stable, especially when disturbed by construction operations, and all underground structures will move with the ground. The extent and type of ground movement together with the structural flexibility of the underground structure will determine the structures' performance. Ground movements occur particularly in variable, soft, or sensitive grounds and across seismic faults.

It is recommended that the following measurements of distortions and movements be made at periodic intervals:

- Where vertical or horizontal displacements of structures are evident, bench marks or other reference points should be established at regular intervals and at convenient locations (in the roof or along the walls) along the section under surveillance. These bench marks should be clearly indicated and referenced to stations. Base data must also be established in stable areas.
- Additional reference points should be established in tunnels (particularly in those with "flexible" linings) to monitor changes in diameter. The selected points should be at the springline or horizontal diameter, in the crown, and, if possible, in the invert.
- Periodic surveys should be made by transit, level, or steel tape to determine the changes in position of the reference points in relation to the base data.

Justification:

Where unstable ground conditions exist or are created, the effects of this instability on underground structures must be monitored for the safety of

the structure and to provide guidance for any necessary remedial actions. The data also supplement those gathered in monitoring cracks in concrete.

CONCRETE CRACKS, JOINTS, AND SPALLING

Cracks in reinforced concrete structures are caused by tension stresses produced by bending, shrinkage during hardening, and differential temperatures. Under normal design stress and conditions in dry situations, visible surface cracks are not detrimental to the structure; however, if cracks penetrate the entire section of a structural unit (e.g., shrinkage cracks) that is under water pressure, water may seep into the structure. Depending on the chemical properties of the water, in time the cracks will either seal themselves with deposits of salt compounds in the water or enlarge through the dissolving action of acidic water. Also, the reinforcing steel itself will oxidize (corrode or rust), and spalling or cracking of the concrete around it will expose more steel and hasten the deterioration of the structure. Spalling of concrete may be caused by mechanical damage.

Several different types of cracks and spalling and their effects on structural performance will be examined, and a guideline will be formulated for repair or remedy of each type and situation.

Guideline 3-4 — Cracks

Remedial action is required if water continuously flows into the structure and if the water quality is such that the crack will not seal itself and if the water has a deleterious effect on the fixtures and equipment in the structure. There are several methods of correcting such a situation.

Pointing or Caulking. In this method the face of the crack is first grooved by cutting manually or with a mechanical chisel. Preferably, the groove should be twice as deep as it is wide. Copious water flows may be temporarily relieved by drilling into the crack and installing plastic tube drains.

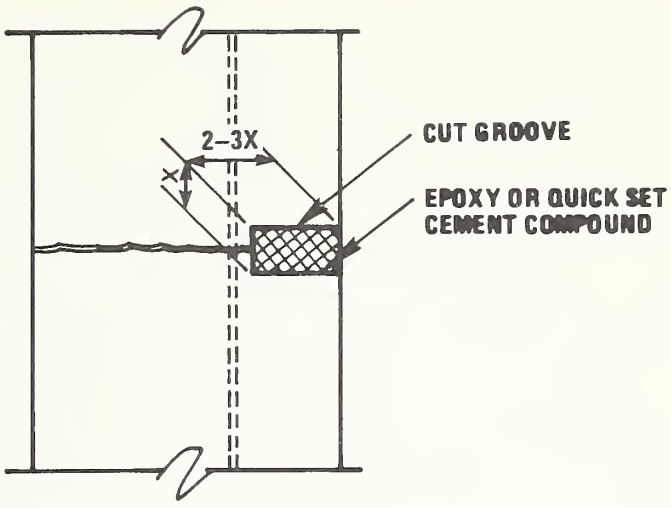
Groove filling material may include epoxy compounds, quick-set cement compounds, or caulking yarns, such as the asbestos cement types. When the latter material is to be used, the depth of the groove should be at least three times its width. Where movements across the crack are likely or where water pressures are appreciable, the groove should be partially caulked and the remainder filled with either epoxy or quick-set compounds. Typical details of this method are shown in Figure 3-4.

Justification:

This method is particularly appropriate for wide or straight cracks, such as construction joints, where the groove can easily be cut along one edge.

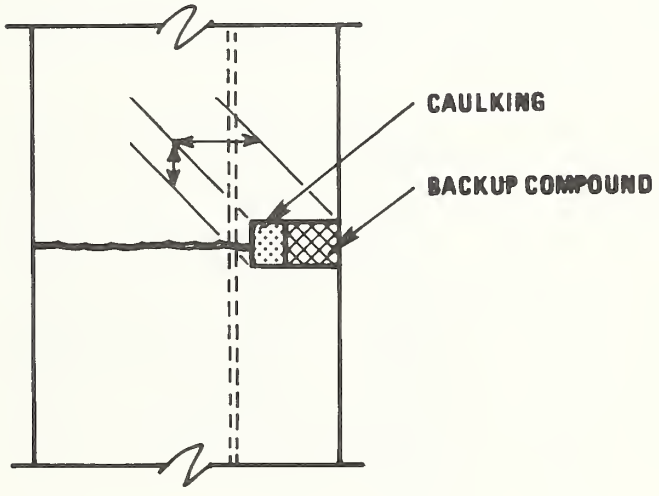
Injection Grouting. In this method a number of injection holes are drilled at an angle to intersect the crack along its length at a distance back from the face of the structure. Alternatively, the grout may be applied through nipples installed in holes drilled for that purpose along the face of the crack. Before grouting, the crack is sealed on the structure face by a "plastic" compound; the water seepage pressure is temporarily relieved by installing plastic tube drains.

Numerous grouting compounds, including quick-set compounds, epoxy compounds, sodium silicate gels, plastic gels such as AM 9 in "Alluvial Grouting", Struct. Eng. Mar. 1972, No. 3, Vol. 50 and "An Introduction to Alluvial Grouting", Paper No. 6598, Institution of Civil Engineers, 1962), are available for injection under pressure. The first two substances appear to be more suitable for static, wide cracks (particularly if the area around the crack is subject to high water pressure), and the gel types are useful for unstable cracks because the gels have finely controllable setting times that permit sealing water-bearing cracks without first having to seal and drain the face of the crack.



METHOD 1

WHERE FUTURE MOVEMENTS
ARE NOT ANTICIPATED



METHOD 2

WHERE MOVEMENTS ARE EXPECTED

Figure 3-4. CRACK SEALING – CAULKING

Justification:

This method is effective for sealing numerous irregular cracks, and the gel materials are particularly suitable where movement is likely to continue in the joint. However, considerable experience is required for successful execution of this method. For typical details of these methods see Figure 3-5.

Guideline 3-5 — Expansion Joints

Both expansion and contraction joints differ basically from "cracks" in that they are purposely formed in the structure to accommodate shrinkage and temperature-caused movement that may continue for many years after construction has been completed. Both types of joints are formed straight. Expansion joints provide a finite gap of approximately one-half inch between structure elements, and control joints occur when the concrete shrinks and consequently cracks along grooves which were formed in the structural elements to provide the planes of weakness.

Leakage in expansion joints occurs around the water bars and is caused by faulty compaction of the concrete around the water bar surface or tearing of the water bar. Because of the surface area and the configuration of the bar, the injection method described in Guideline 3-4 is difficult to use. Therefore, one or the other of the face water seals shown in Figure 3-6 is recommended. Both details presuppose that the arrangement of electric conduits and other services on the surface will permit installation without excessive cost.

Justification:

Detail 1 shows an economical method for diverting the water entering the roof and walls into the structure drainage system. If it is of adequate size and the incoming water does not deposit excessive salt, this remedy should be reasonably maintenance free.

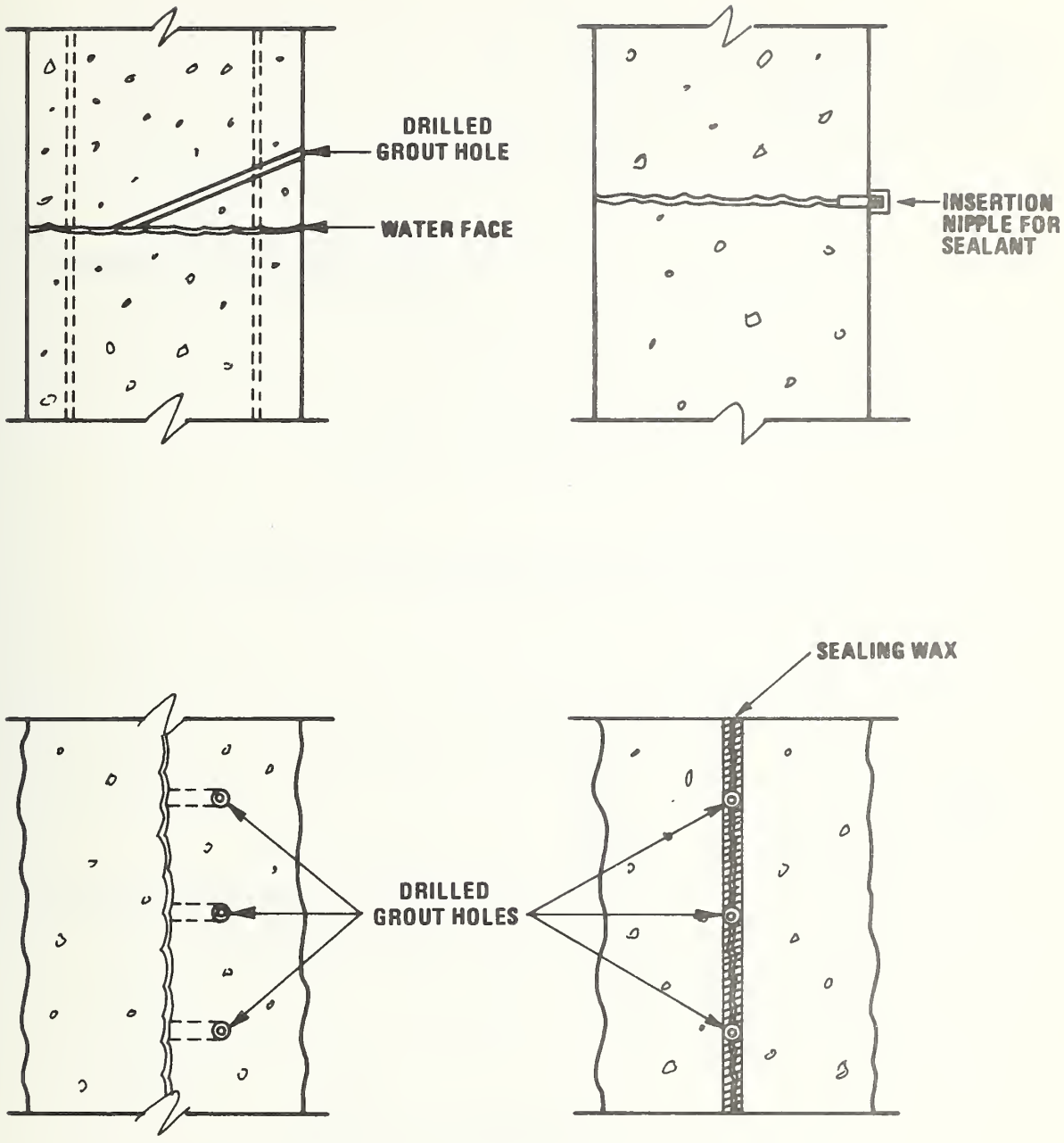
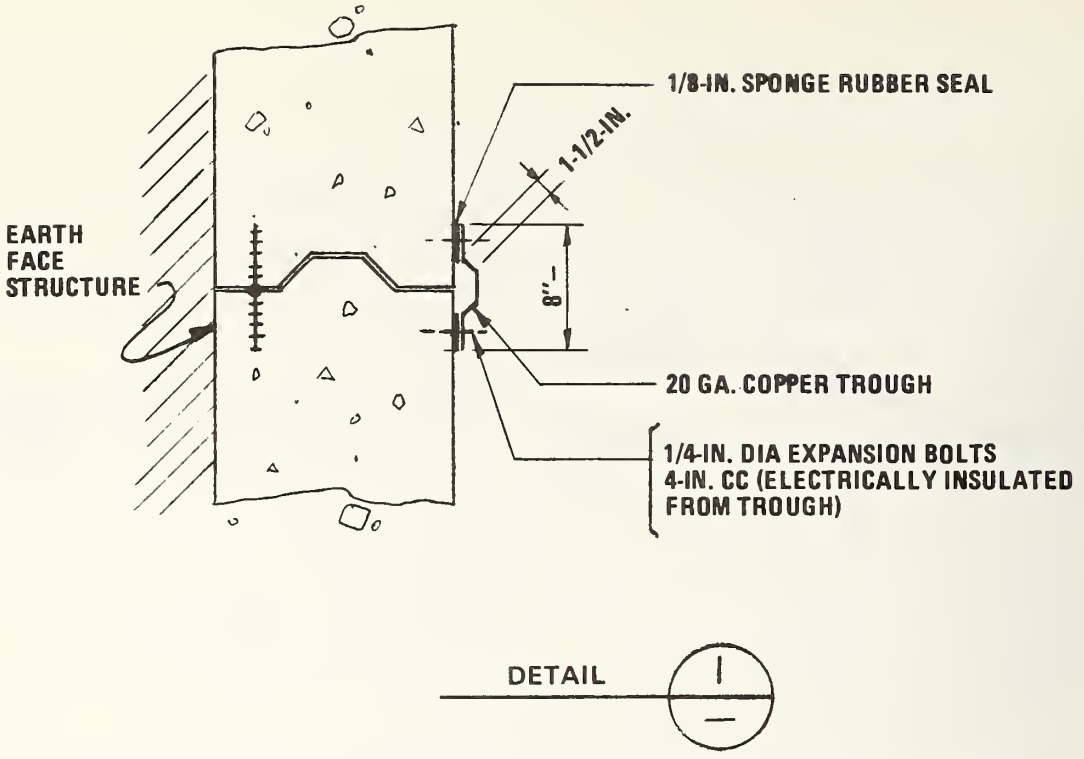
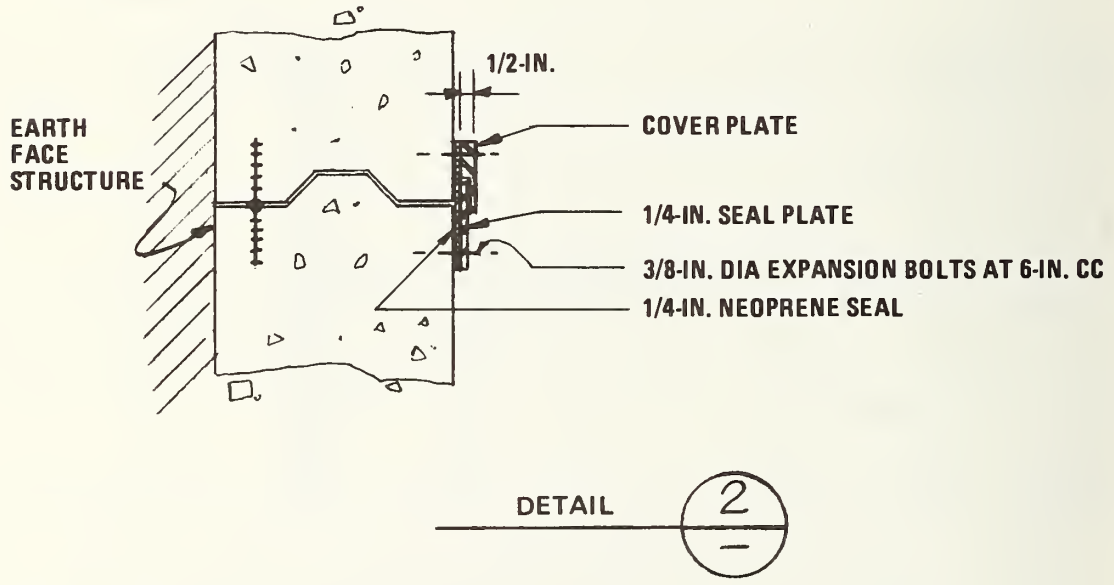


Figure 3-5. CRACK SEALING – GROUTING



NOTE: FOR USE IN SITUATIONS WHERE IT IS ADVISABLE TO DIVERT WATER FROM ROOF AND WALLS INTO THE STRUCTURE DRAINAGE SYSTEM.



NOTE: FOR USE IN WATER CONDITIONS WHERE IT IS DESIRABLE TO LIMIT WATER FLOW INTO STRUCTURE.

Figure 3-6. JOINT REPAIR SEALS

The method shown in Detail 2 is more costly than the method in Detail 1, but is should be entirely free of maintenance and, in the event of heavy water flow, would reduce pumping costs and drainage maintenance. While the installation of the seal in the roof and walls is straight forward, in the invert this installation may be considerably complicated by the presence of tracks and drainage system. Joints there may have to be sealed by soil grouting or other means.

Guideline 3-6 — Control Joints

If the movements across the joints are appreciable and continuous, the leakage should be stopped with whichever detail of Guideline 3-4 is more appropriate. If the movements are slight, any of the methods described in Guidelines 3-2 and 3-3 may be satisfactory.

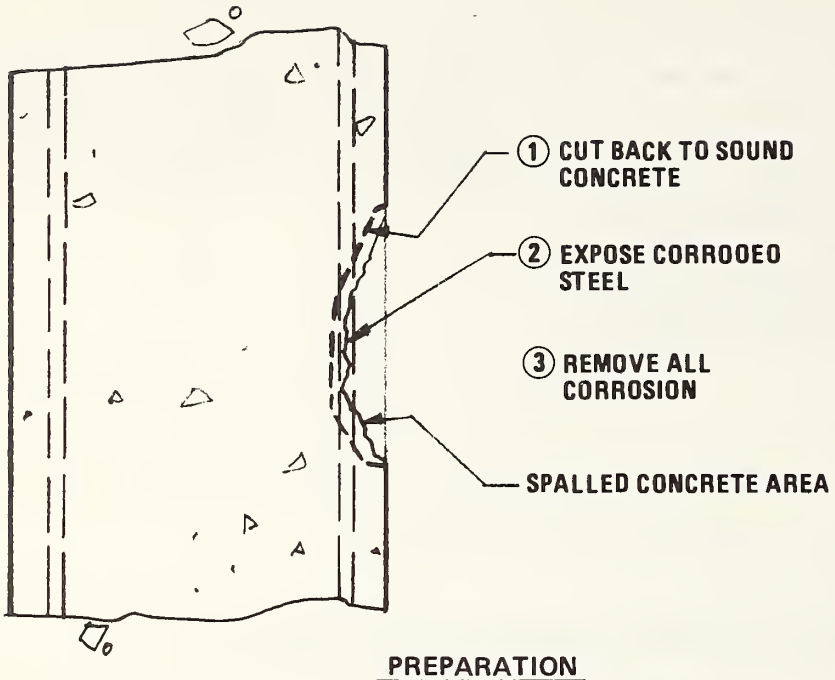
Justification:

Contraction joints, as distinct from cracks, by the nature of their design tend to attract any movement imposed on the structure. Therefore the method recommended for expansion joints in Guideline 3-5 may provide the most satisfactory long-run solution to the problem of leakage in contraction joints.

Guideline 3-7 — Spalled Concrete

Spalled or otherwise defective concrete can be repaired by several methods; three are listed here. The repair procedure includes preparation of the surface, actual repair, and curing. A typical situation is illustrated in Figure 3-7.

> Preparation — The defective area should be cut back to sound concrete in such a way as to avoid feathered edges. All of the reinforcement that is corroded should be exposed and the corrosion removed by wire-brushing, sandblasting, or other methods. Care should also be taken to ensure that the backs of the reinforcing bars are properly treated



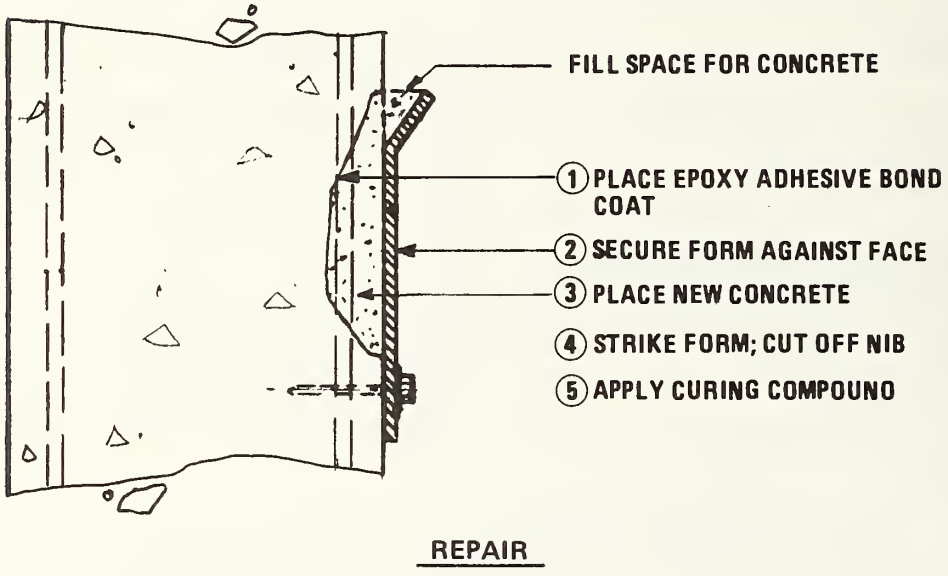


Figure 3-7. SPALLED CONCRETE REPAIR

- Repair Method — A form should be prepared as shown in Figure 3-7 and secured tightly against the concrete face. Before the form is affixed, the concrete and the reinforcement to be repaired should be coated with epoxy adhesive. The form should be fixed in position and the new concrete placed before the adhesive hardens. The new concrete should be of a comparable strength to that of the existing structure, and the aggregate and workability should be sufficient to provide dense, sound concrete. Compaction, particularly where the concrete must be consolidated behind reinforcement, should be assisted with surface vibrators.
- Method 2 — Small areas with shallow depth may be repaired by manually applying cement mortar over a prime coat of epoxy adhesive. The mortar should be of the same strength as that in the original structure. A correctly formulated epoxy mortar could also be used.
- Method 3 — For areas requiring extensive repair, an economical approach is to use shotcrete of a coarse sand aggregate. The shotcrete should be applied by the method described in "Recommended Practice for Shotcreting." ACI 506-66, and Ref. 1, "Shotcrete Practice in Underground Construction," Federal Railroad Association, ORND 79-90, UILU-Eng., 75-2018. The appearance of the repaired area can be improved by troweling immediately after application.
- Curing — When the concrete has hardened sufficiently, the form should be removed, the pouring nib cut back, and a curing compound applied to the concrete. The curing compound should be pigmented and two coats applied, the second at right angles to the first.

In major structural repair (such as the ends of beams or corbels) additional reinforcement can be bonded into the existing concrete by drilling and setting the reinforcement in place with an epoxy mortar.

Justification:

When making such repairs as those described above, several principles should be carefully observed:

- The working area must be prepared so that feathered edges are avoided, and

- All corrosion must be removed from the reinforcement.
- The epoxy adhesive must be used to help make a tight bond between the new and the old concrete because concrete shrinks as it hardens and tends to pull away from the old concrete surface. It is also important not to make the new concrete richer nor stronger than it has to be.
- Since repair concrete normally consists of thin layers and is likely to dry and shrink rapidly, proper curing is essential.
- Although several recently introduced adhesives and repair systems are available, lack of historical performance data prevents their recommendation.

SOIL GROUTING

An alternative (and sometimes supplemental) method for stopping the inflow of water is to inject grout into the water-bearing solid layers surrounding the structure. In this section, the discussion of soil grouting is limited to the requirements of waterproofing a leaking structure.

This waterproofing requires injecting the surrounding soil with a grout to fill both the voids in the soil and the cracks in the structure. The injection may be accomplished either by drilling from the ground surface to the top of the structure and installing injection pipes or by drilling from inside through the structural wall. Strength from the grout is not required to make the structure watertight.

There are three principal types of grout and several variations and formulations within each type. A particular grout is selected for the pore size and grain base of the ground to be injected.

- Portland cement is generally applied to coarse sands and gravels
- Sodium silicate is used with medium sands. Bentonite has also been used successfully to stop water in these sands

- Organic polymers are used for fine sands with some silt and other appended material.

Guideline 3-8 — Soil Grouting

Soil grouting to waterproof subway structures is recommended when difficult leakage situations are encountered. This method of waterproofing may be used alone or in conjunction with the methods discussed previously.

Justification:

This method is particularly applicable to structures that have multiple, close-spaced, water-carrying cracks. Recommended procedures for performing soil grouting are outlined in Guideline 3-9, and describes appropriate grouts for various soil conditions and techniques for their injection.

Guideline 3-9 — Formulating a Soil Grouting Program

Figure 3-8 illustrates the steps to be taken in proper order to formulate the most effective soil grouting program.

Justification:

Soil grouting is highly complex work that requires a combination of scientific knowledge and practical experience. Unless all of the procedures indicated in Figure 3-8 are instituted, the program is likely to suffer from inefficiency, ineffectiveness, or, at best, from a slow and expensive learning curve. The justifications for many of the procedures are self-evident and are discussed only in the detail that is considered useful or has not been covered previously in this section.

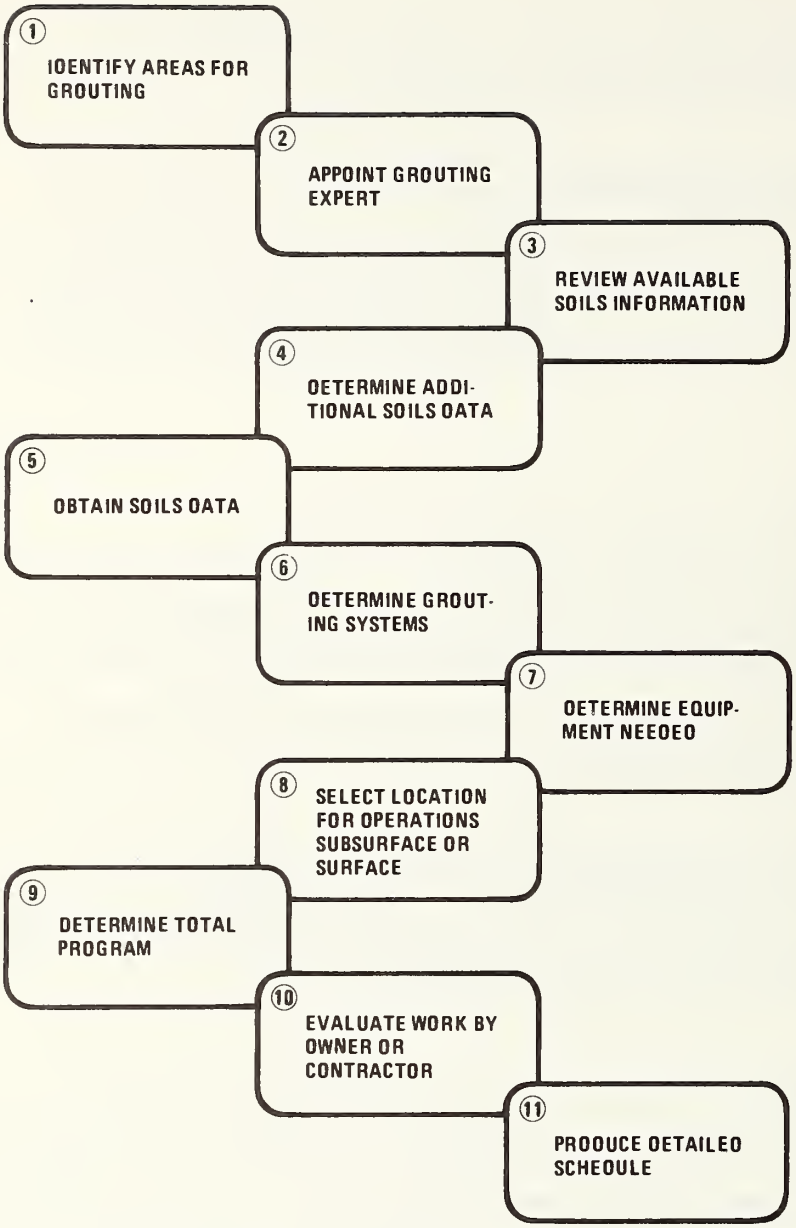


Figure 3-8. FORMULATING A SOIL GROUTING PROGRAM

The success of this process depends on selecting the correct chemical or other grouting system for the type of soil to be grouted and on the skill and experience of the operator.

Determining the most economical program for a specific transit property requires consideration of the ground along the route (which may vary widely in composition and require more than one grouting system) and of the space available for working equipment, either underground or on the surface.

The grouting expert must be a competent soils engineer or contractor with experience in all facets of soil grouting systems and techniques. He will assist the owner in establishing the program, particularly with Steps 3 through 8 of Figure 3-8. Although it may not be feasible to determine the total program until some actual grouting is done, an attempt should be made to quantify the work at an early stage so that Step 10 can be evaluated.

In determining whether the work should be done by the Owner or by a contractor, the following factors should be considered:

- If other system maintenance is performed by a contractor,
- Extent and quantity of grouting — attempts to confine grouting to local areas of structure leakage are often unsuccessful and consideration must be given to a progressive system that covers 100 percent of the structure,
- Number of types of grouting systems required,
- Location of grouting operations,
- Support equipment available, such as rail work vehicles and power sources,
- Skill and availability of Owner's maintenance personnel, and
- The possibility of utilities in the locality of the work being damaged or filled with grout and the consequent responsibility.

Generally, if the grouting operation will be performed from the surface, it will require relatively expensive drilling equipment and is probably more economically done by a contractor.

EXPOSED STEELWORK

All exposed steelwork must, of course, be protected. In this section, steelwork will be discussed in two categories: miscellaneous and structural.

Miscellaneous steel shall be understood to include all steelwork other than load-bearing main structure members. This category includes such accessories as stairs, landings, ladders, hatchways, gratings, manhole covers, doors and framing, pump and fan supports, brackets, and hangers. The chief maintenance requirement for miscellaneous steel is protection from corrosion.

Structural steel includes beams and columns and often, but not always, supporting main concrete or masonry slab or wall elements. Maintenance of structural steel frequently requires structural repair of damage done by corrosion as well as protection against corrosion.

Guideline 3-10 — Miscellaneous Steel

Corroded steel that is, and that will continue to be, exposed to wet, moist, salty, or other corrosion environments should be repaired in the following manner:

- Preparation — Rust must be removed until bright metal is visible; a protective coating should then be applied to the metal. Rust may be removed mechanically by penumatically operated scrapers or "needles," or by portable sand blasting equipment. The equipment list shows typical equipment. High pressure water jetting (with pressures up to 5,000 psi) has also proved effective in removing heavy rust laminations from steelwork.

- Protective coatings should be applied to rust-free, dry metallic surfaces only. High-quality protective coatings recommended are:

  Inorganic zinc silicate 3 mils thick followed by one coat of catalyzed epoxy,

  Two coats of amine-adduct epoxy, and

  Where wet surfaces are unavoidable, a polyamide should be substituted for an amine-adduct epoxy.

The above coatings are listed in order of their probable durability for severely corrosive situations (refer to ACI SP-49).

Justification:

The importance of thoroughly preparing the surfaces to be treated cannot be overemphasized. They must always be taken all the way down to bright metal. This practice coupled with correct application of the recommended coatings will achieve a high degree of protection and will minimize future maintenance costs.

Surfaces and corners that are hard to reach must be given special attention during the preparatory work. If practical, steel items that are bolted to concrete surfaces and that are corroded at the interface should be removed so that the protective coating can be applied and the steel reset in a sealastic compound.

The high pressure water jetting method (used in London) appears to have the additional advantage of eliminating the fine dust and grit generated by the other methods and the subsequent clean-up.

Corrosion often attacks cast-in bolts, angles, and other items at the face of the concrete. Because the item may become loose in the concrete or because the concrete may crack, moisture can enter continuously and accelerate the corrosion process. In such cases, the concrete face should be cut back as far as the corrosion is evident, the metal prepared,

and protective coatings applied. The cut should then be filled with a sealastic or with an epoxy cement mortar. Pockets and corners in steelwork that collect water should be filled with bitumin or mortar to create watersheds.

Guideline 3-11 – Repair of Structural Steel

When structural elements must be repaired because they have lost metal, the following recommendations should determine the repair program:

- If site welding is required, the composition of the parent metal must be determined, and the repair metal and the electrode must be compatible with the strength of the required weld.
- The appropriate sections of the American Welding Society Inc. (AWS) codes should be followed for all the work.
- Completed welds should be inspected by qualified inspectors and important welds scanned with ultrasonic probes.
- Access to the work must be adequate for both making and inspecting the weld.
- If temporary supports of the structural member are necessary to make the repair, the supports should be part of the engineering design.
- The specifications should cover the following items:

  Old supports for new beam or column seatings should be checked for soundness before the loading is applied,

  Defective concrete or masonry should be replaced with sound material, and

  Seatings should be dry packed or filled with non-shrink grout or mortars.

Guideline 3-12 – Corrosion Protection of Structural Steel

After the structural repairs have been made, it is recommended that all metal requiring corrosion protection be treated in the method described in Guideline 3-10. Wherever possible, water ingress should be prevented by local draining or by grouting; dampness may be alleviated

by ventilation. If the steelwork is normally hidden by architectural finishes, provision should be made for removable panels or other access to permit periodic inspection.

Justification:

Repairing structural deficiency is only one part of maintaining structural steel; recurrence should also be prevented. Observance of the preceding recommendations will minimize expensive maintenance.

SEGMENTED LINED TUNNELS

Such tunnels are composed of a single lining of segmented rings of cast iron, steel, or concrete. The segments are bolted on to each other to form a ring, and the rings are bolted one against the other with either high- or low-strength bolts. Water is prevented from coming in between the segments by caulking the grooves provided all around the matching faces of the segments. Grommets under washers make the bolts watertight.

Correction of leaks generally involves replacing grommets or tightening loose bolts and repairing the caulking. In difficult situations, leaking may be corrected by injecting grout into the soil through the tunnel lining. Other repair requirements include strapping cracked cast iron, repairing welds in fabricated steel, and repairing damaged protective coating. In concrete-lined tunnels, the most frequently required repairs are of cracks and chips.

Guideline 3-13 — Repair of Caulking

Before caulking is repaired, all loosened bolts should be tightened. If they are badly corroded, they should be replaced and regrommeted. Old caulking should be cut out as far as it is defective, the groove cleaned, and new caulking inserted using the correct width of caulking tool. It is essential, therefore, to tighten the bolts enough to prevent further movement before the caulking is repaired.

Justification:

Leaks in segment joints are usually caused by movement in the tunnel lining which loosens bolts and causes the interface of the segments to work against each other and loosen caulking. It is, therefore, essential to tighten the bolts sufficiently to prevent further movement before repairing the caulking.

High-strength bolts, which are generally used for steel segments and sometimes for cast iron ones, tend to suffer from stress, corrosion, and fatigue. Corroded bolts will often fracture at the root of the thread when they are being torqued; therefore, a certain number of replacement bolts should be anticipated.

Guideline 3-14 — Caulking Material

Where the original caulking material (lead in metallic linings and asbestos cement yarn in concrete linings) has generally proved satisfactory, the same material should be used in the repair program after further movement has been prevented by tightening the bolts. If, however, movement is expected to continue, an expansive caulking yarn such as "Sealite" should be placed in the root of the groove before the lead or asbestos cement yarn is installed. (See Appendix F of the "Rapid Transit Subways - Maintenance and Engineering Report" Report No. UMTA-MA-06-0025-78-1.) Such a detail is shown in Figure 3-9.

Justification:

Once they have hardened, both lead and asbestos cement yarn have little elasticity and, therefore, will loosen and allow leakage and segment joint movement to occur. Expansive caulking swells when wet and follows joint movement which detains the water. The backup material of lead or asbestos cement yarn will keep the caulking in place.

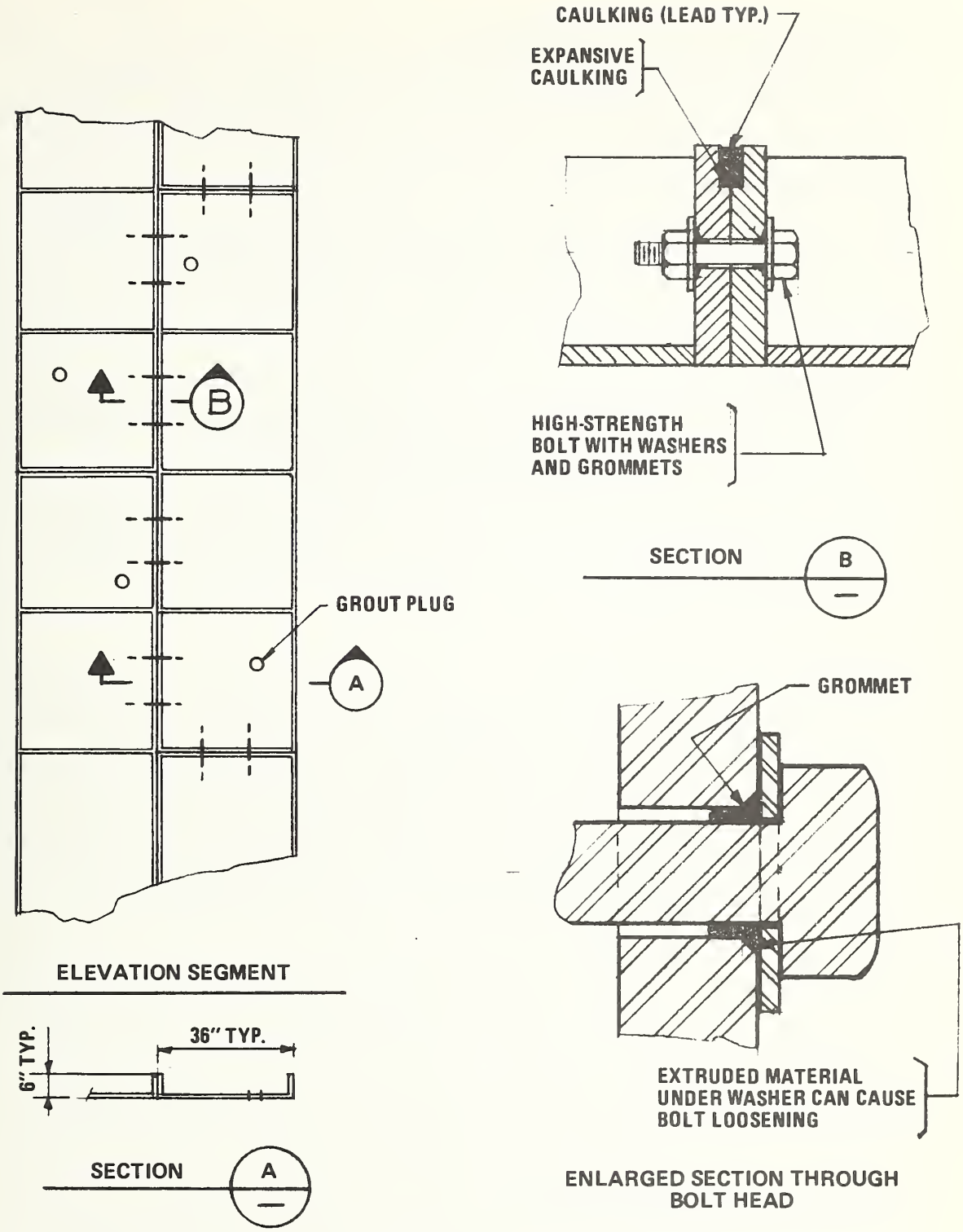


Figure 3-9. TYPICAL STEEL SEGMENT – SEALANT AND GROMMET DETAIL

Guideline 3-15 — Grommet Material

During tightening of the bolts, polyethylene, a frequently used grommet material, may be extruded as a relatively thick layer under the washers. Under sustained pressure from the bolt, this layer will eventually creep and thus allow the bolt to become loose. Uncured butyl rubber is recommended for consideration as a substitute for polyethylene in the grommets.

Justification:

For both high- and low-strength bolts to remain tight, there must be a hard, unyielding bearing surface between the washer and the segment. This may be more easily achieved by the softer butyl rubber grommet than by the harder polyethylene, especially in concrete segments with the lower strength bolts.

Guideline 3-16 — Soil Grouting

Where it is impossible to prevent segment joint movement and where leakage is severe, soil grout injection may be an appropriate way of stopping the leakage. In many cases, this may be conveniently done through the grout plug holes provided in the segmented lining. The procedure for this grouting is the same as described in Guideline 3-8.

Justification:

Areas where water is a troublesome problem may also have bad or soft soil, and these conditions generate continual movements in the tunnel lining. Waterproofing by means of soil grouting has proved satisfactory.

Guideline 3-17 — Channel Drains

Diverting seepage by means of channel drains into the tunnel drainage system is recommended in certain situations. Such channel drains preferably should be fabricated plastic material and may consist either of

narrow, single channels or of corrugated sheets. Details should readily permit periodic inspection of the structure behind. Typical systems are illustrated in Figure 3-10.

Justification:

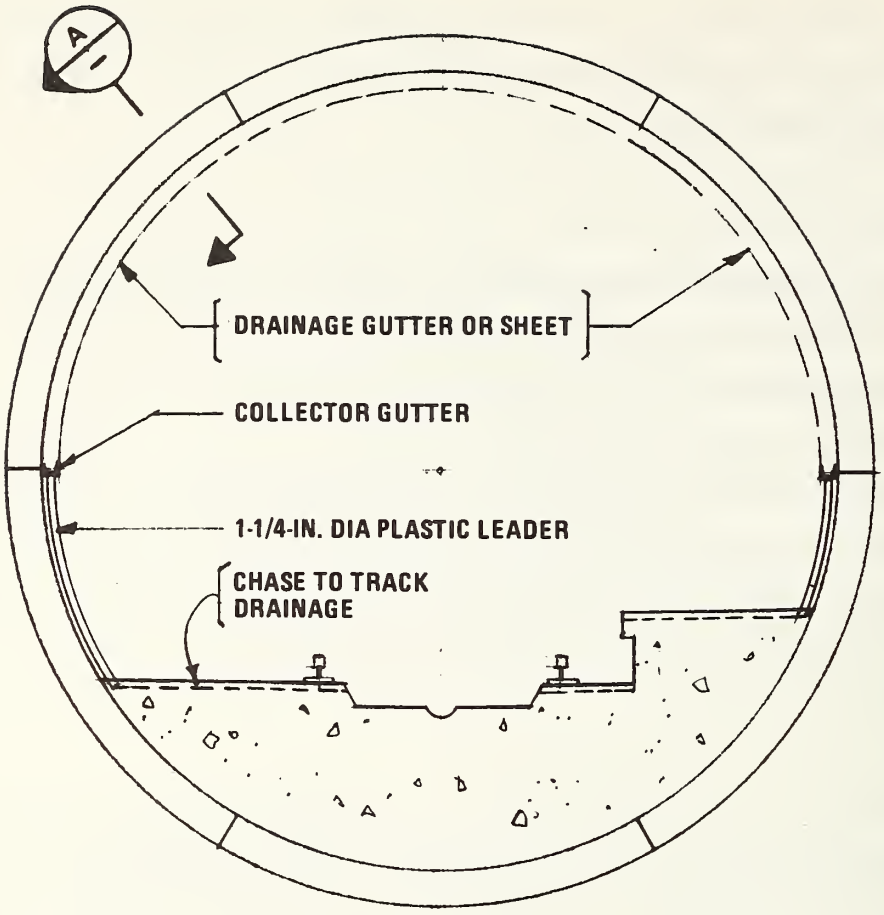
Where other methods of waterproofing are difficult to install and where services within the tunnel permit, channel drains have proved to be a simple and economical way of solving water problems in a tunnel. Details of the drainage system and selection of material to be used should be governed by an aim toward minimizing continuous maintenance of the system itself. Plastic is preferable to other materials because of its lightness which makes it less hazardous if it becomes detached. Even then, however, the method should be considered only as temporary expedient until conditions permit installation of a permanent water barrier.

Guideline 3-18 – Corrosion Protection

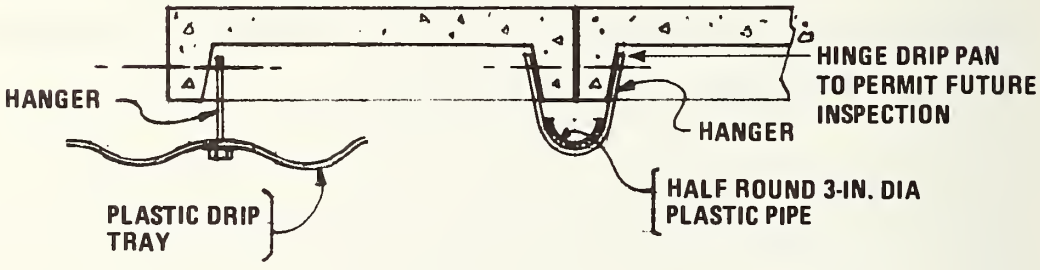
Where surface corrosion occurs in metallic linings, remedial procedures similar to those described in Guideline 3-10 should be undertaken. Particularly vulnerable locations include the interfaces between the concrete tunnel invert and the walkway where the concrete shrinks from the lining to create cracks or pockets for water to lie in. Such pockets or cracks should be cut back to fully expose all corroded steel, and after the repairs are made, the pockets should be filled with an elastic material and graded to prevent water from collecting there again.

Justification:

The comparatively thin fabricated steel lining in contemporary use should be protected against corrosion, particularly in locations that are difficult to reach. Figure 3-11 shows details of a corrosion repair between the concrete invert and the liner.



SECTION THROUGH RUNNING TUNNEL



SECTION A – DETAILS OF ALTERNATIVE ROOF DRIP COLLECTORS

Figure 3-10. TUNNEL ROOF DRIP COLLECTOR SYSTEMS

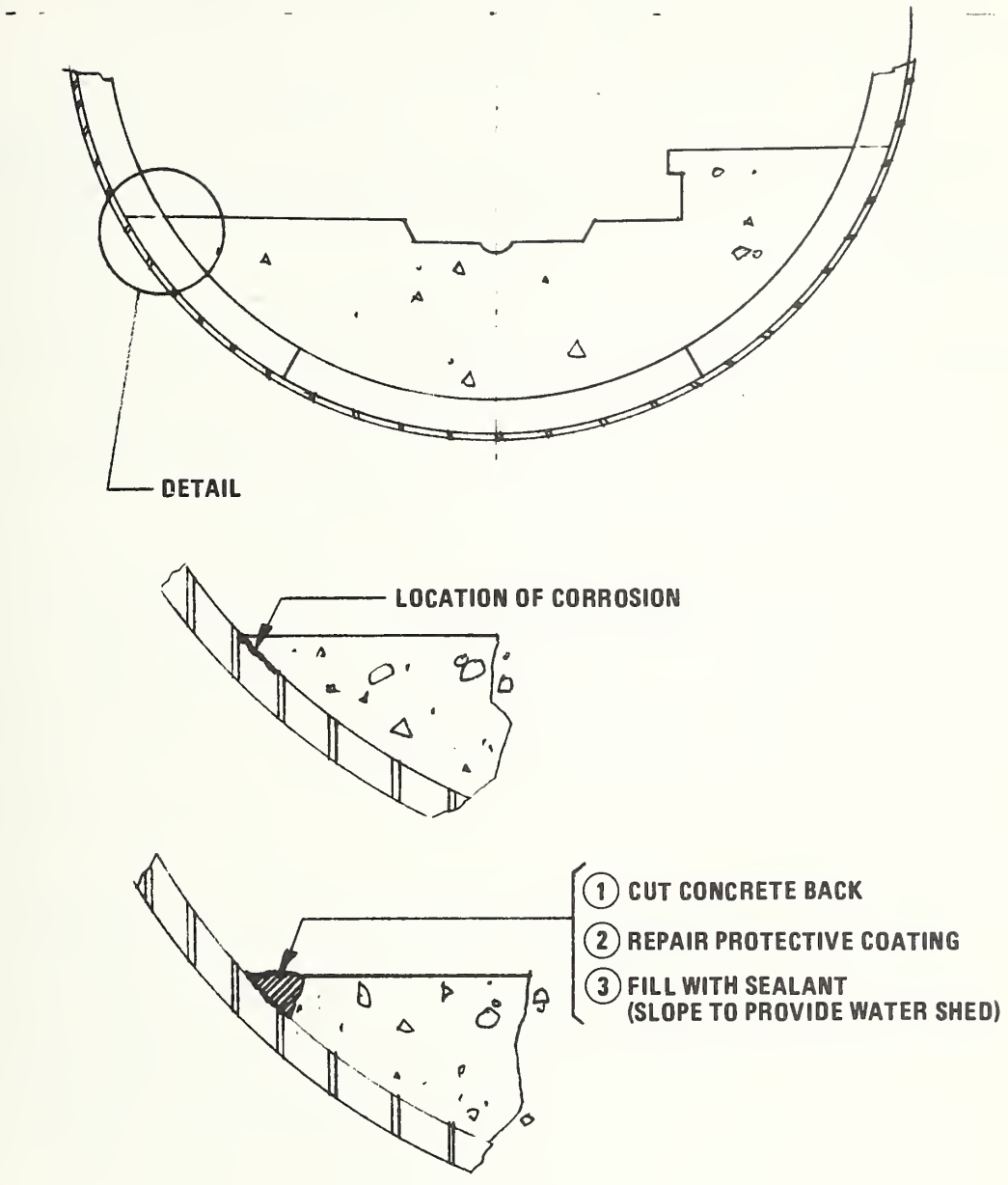


Figure 3-11. DETAIL OF CORROSION REPAIR

If properly grommeted, bolts do not normally suffer from corrosion between the grommeted faces. Because ventilation is normally good in a trackway structure the exposed portion of the bolt is not generally vulnerable to corrosion and is left unprotected.

Corrosion protection of the outside surface of the metallic liner is covered in Guideline 3-10; protection by cathodic methods is discussed in the Rapid Transit Subways - Guidelines for Engineering New Installations to Reduce Maintenance.

Guideline 3-19 — Structural Repair of Metallic Linings

Cracked cast iron linings should be repaired by bolting splice plates or angles across cracked flanges or by strapping cracked web plates by bolting into holes drilled and tapped into the web plates.

Failed welds in steel linings should be cut out and rewelded. Buckled web plates and flanges should be reinforced by welding in additional metal. In making these repairs, care should be given to properly applying protective coatings at all necessary places.

Justification:

Failure in cast iron segments is usually caused by excessive soil movement. Generally, the cracking relieves the stress and the structural integrity of the tunnel does not suffer, but it is important to prevent the fractured pieces from being dislocated from each other. Fabricated steel liners are usually flexible enough to accommodate most ground or other movement without accident; however, point loads from adjacent foundations or rocks may cause plate bending or weld failure. Such problem areas should be repaired and reinforced.

Guideline 3-20 – Repair of Precast Concrete Liners

Cracks in precast concrete segments should be repaired by epxoy injection (see Guideline 3-4), and spalling and exposed reinforcement should be repaired by properly formulated epoxy cement mortar. Preparation of the spalled areas and reinforcement are described in Guideline 3-8.

Justification:

Because the concrete segments are relatively thin, their repair requires the epoxy grouting and mortar system described above.

Guideline 3-21 – Filter Drains

Where filter drains to relieve water pressure are provided in tunnels and other structures, all steps should be undertaken to ensure that they continue to function as designed. For this effort, recording of inspection and maintenance is considered essential. In situations where frequent filter clogging is experienced, the filter material grading may be modified to improve the condition. The use of readily replaceable filter cartridges should be considered.

Justification:

Neglect of filter drain maintenance may result in plugging of the filter material by salts in the water or solids, and a buildup of water pressure around the tunnel or other structure. This could lead to increased seepage and even structural distress.

MAINTENANCE OF MECHANICAL AND ELECTRICAL EQUIPMENT

ESCALATORS, ELEVATORS, PUMPS, FANS

A well designed and implemented maintenance program will extend the service life and reliability of the components of mechanical and electrical equipment, reduce the incidence of breakdown, and enhance its safe working.

In the stations, reliability and safe working of escalators and elevators are particularly important for the well being of the patron and for maintaining smooth vertical transportation to and from the trains. In the trackway, reliable functioning of pumps and fans is mandatory if the possibility of interruption of train service from flooding is to be avoided and if smoke control is to be ensured when such emergencies arise.

The cost of a proper maintenance program for each of these items should be more than offset by the money saved by the reduction in emergency repairs and by extension of service life. An excellent discussion of various aspects of this subject is given in "Maintenance for Commercial Buildings," Buildings Stamats Publishing Company, Cedar Rapids, Iowa.

The procedures for periodic inspective and preventive maintenance for escalators, elevators, pumps, and fans are similar, but the degree of effort and schedule is much greater for the first two items than for the latter. The following guidelines are ordered so that those that are common to all items precede the ones for individual items.

Guideline 3-22 — Equipment Records

Record cards comprising base data and maintenance history should be established for each unit and kept in the equipment location.

Justification:

Figure 3-12 is a typical Base Record form with some of the headings indicated of basic data for mechanical/electrical equipment. Such information, available at the equipment location, is valuable to the maintenance staff, especially when staff changes are made. The data should also be incorporated in the transit system-wide inventory records.

Figure 3-13 illustrates a suitable Maintenance History card which may be conveniently reproduced on the reverse side of the base data card and on which the periodic maintenance and repairs should be recorded. Some typical entries by the maintenance staff are shown.

Such information is obviously important for a number of reasons including facilitating the work of the maintenance monitor and aiding the maintenance manager in assessing equipment performance, maintenance costs and schedules, spare part inventories, and replacements.

Guideline 3-23 — Maintenance Frequencies

For each type of equipment, frequencies must be established for the different required maintenances. These should be based on the manufacturers recommendations, the intensity of service imposed on the equipment, and its age.

Justification:

Effective maintenance must be timely. A schedule of different types of maintenance being undertaken over different time periods

ITEM NAME			INVENTORY NO.		
LOCATION					
			SPARE PARTS		
MECHANICAL			DESCRIPTION		PART NO.
MANUFACTURER					
SERIAL NO.					
MODEL					
TYPE					
RPM			ADDITIONAL INFORMATION		
CFM					
GPM					
DRIVES					
BEARINGS					
CONTROLS					
OILING SYSTEM					
CONTROLS					
GOVERNORS					
			SPARE PARTS		
ELECTRICAL			DESCRIPTION	NAME	PART NO.
MANUFACTURER					
SERIAL NO.					
MODEL					
TYPE					
H.P.			ADDITIONAL INFORMATION		
VOLTS					
AMPS					
PHASE					
BEARINGS					
CONTROLS					
OILING SYSTEM					
BRUSHES					

Figure 3-12. EQUIPMENT BASE DATA RECORD

DATE	MAINTENANCE PERFORMED
–	EQUIPMENT INSTALLED STARTUP CHECKED OUT
–	BEGAN MONTHLY MAINTENANCE M/M
–	TOPPED OIL ADJUSTED CHAIN TENSION
–	M/M – TIGHTENED BASE BOLTS DRIVE MOTOR

Figure 3-13 MAINTENANCE HISTORY RECORD

and formalized schedules will help both to ensure that the work is being undertaken as established and to optimize economic maintenance procedures.

When defining maintenance schedules, the service imposed on the equipment should be taken into account. This is particularly true of escalators and elevators which experience wide degrees of usage even in the same station. A typical preventive maintenance inspection frequency schedule is reproduced in Figure 3-14.

Guideline 3-24 — Service Data

Time and frequency of operating data for equipment should be recorded.

Justification:

Such data are required in connection with optimizing the maintenance schedules discussed in Guideline 3-23 and can further assist the maintenance manager in his evaluation of equipment performance and other subjects discussed in Guideline 3-22. In addition, the data are essential for economic comparative evaluations of equipment from different manufacturers. Service data should include:

- Escalators — Operating hours in each direction and at different speeds if these are variable; numbers of stops, if applicable, over "no load" periods;
- Pumps — Numbers of cycles and durations; and
- Fans — Hours of service.

Guideline 3-25 — Electrical Maintenance Procedures

Procedures should be developed for maintenance and testing of electric motors, starters, and related components for the escalators, elevators, pumps, and fans.

Type of Equipment	Frequency
Disconnecting switches	SA
Electrical grounds and grounding systems	SA
Electrical instruments	SA
Electrical potheads	Q
Electrical relays	Q
Cathodic protection system	SA
Electric motors and generators	
Running inspection	Q
Shutdown inspection	SA
Electrical systems (buildings)	SA
Lighting (buildings)	SA
Ventilation and exhaust systems	M
Plumbing	M
Pumps	M
Preventive maintenance inspection — elevators and escalators	M

Frequency Code: M = Monthly
A = Annually
Q = Quarterly
SA = Semiannually

Figure 3-14. TYPICAL PREVENTIVE MAINTENANCE INSPECTION FREQUENCIES

Justification:

The basic procedures for essential preventive maintenance and testing of this equipment are described and discussed in a number of commercial and technical manuals; e.g., "Maintenance Hints," Westinghouse Electric Corporation (HB-6001-MM). Such manuals provide a sound basis for developing procedures for each item and type of equipment installed.

General conditions for maintaining electric equipment include cleanliness, dryness, tight fastenings, and lubrication.

Guideline 3-26 — Preventive and Replacement Escalator Maintenance Procedures

Maintenance procedures for all components should be developed according to each manufacturer's instructions and other established procedures or applicable local safety regulations and the American National Standard and Safety Code (ANSI) for Elevators, Dumbwaiters, Escalators, and Moving Sidewalks and ANSI for Inspection of Elevators, Escalators, and Moving Sidewalks — Inspectors Manual.

Justification:

Escalators comprise a multiplicity of bearings and moving parts, electric drive motors and mechanisms, electrical controls, and safety devices. The maintenance of the mechanical components involves the following general areas:

- The correct lubrication undertaken at defined frequencies,
- Adjustments of mechanisms, and
- Replacement of worn parts or of mechanisms.

Electrical components, including controls and safety devices, require:

- Cleaning and lubrication,
- Inspection checking or testing for satisfactory functioning and adjusting, and
- Replacing parts and components.

Many of these activities are performed at different frequencies for different components. Typically, in subways these may be:

- Semiweekly,
- Semimonthly,
- Monthly,
- Quarterly,
- Semiannually,
- Annually, and
- 5 to 7 years.

The first six relate generally to lubrication, general inspection and checking, and minor adjustments, replacing of handrails, etc.; the last is major overhaul including replacement of steps and other components. Safety tests every six months are normally recommended.

Guideline 3-27 – Preventive and Replacement Elevator Maintenance

Maintenance procedures for all components should be developed according to each manufacturer's instructions or other established procedures or applicable local safety regulations and the American National Standard and Safety Code (ANSI) for Elevators, Dumbwaiters, Escalators, and Moving Sidewalks and ANSI for Inspection of Elevators, Escalators, and Moving Sidewalks – Inspectors Manual.

Particular attention should be directed towards lubrication and other maintenance "do's and don'ts" for safeties and guide rails. In addition,

the importance of safety instruction to the maintenance staff and precautions to be implemented when working on this equipment must be recognized.

Justification:

Elevators have fewer moving parts and components to maintain than do escalators, but the safe functioning of their controls and safety devices have far greater impact upon the safety of the passenger. Strict observance of required maintenance procedures is, therefore, mandatory to achieve a high standard of safety.

Maintenance of the mechanical and electrical components, particularly for rope escalators, involves the same general areas as described in Guideline 3-25. Components related directly to the safe working of the elevator and which require particularly rigorous attention include: the ropes; the motor controls and brakes; and the governors, safeties, and guides. Door mechanisms are normally a major source of malfunction and nonscheduled maintenance; therefore, thorough routine maintenance is important here.

Hydraulic elevators are basically safer and require less maintenance than suspended elevators because of the fewer components involved. The same care and attention must be directed to maintaining the components related to safety, such as the controls (safeties and related equipment are usually not required). In addition, the various hydraulic seals, filters, etc., must be inspected and maintained.

Typical maintenance periods for the foregoing are:

- Weekly,
- Monthly,
- Semiannually,
- Annually,
- 2 years, and
- 3 years.

The weekly and monthly periods are appropriate for lubrication of components, inspection and cleaning of electrical controls, etc.; complete inspection occurs semiannually; rope maintenance under specified conditions is performed annually or biannually; and the hydraulic tanks are cleaned every 3 years.

Guideline 3-28 — Cleanliness and Condition of Machine Rooms, Hoist Ways, and Equipment

Escalator and elevator machine rooms, equipment space, and elevator hoistways should be kept free from debris, dust, and water. No flammable materials should be stored. Equipment should be kept free of excessive grease, lubricants, and dust.

Justification:

Reduction or elimination of fire hazard, increased safety for the maintenance staff, and improved performance of the components are all objectives to be attained by this guideline. It is particularly important to keep elevator safety guide rails free of excessive grease and the brakes free from all grease or oil. Dust, water, and oil can cause malfunction of electrical controls, and water, grease, and debris on walking surfaces are potentially dangerous to personnel.

Guideline 3-29 — Safety Inspection of Escalators and Elevators

Periodic inspections should be undertaken by experienced inspectors to verify that all items of equipment conform to safety requirements. The scope of these safety requirements is defined in American National Standards for the Inspection of Elevators, Escalators, and Moving Walks — Inspectors Manual.

Justification:

Inspection emphasizes safety, which assumes considerable importance particularly in the peak travel periods in a busy underground station.

The inspective checks, which may include testing, are directed towards emergency safety devices; smooth stopping, starting, and general running; tolerances and condition of escalator treads, combs, and handrails; and elevator door mechanisms, ropes, safeties, etc. Inspection should also include verification that required maintenance has been performed and machine rooms and equipment are clean.

Guideline 3-30 — Preventive Pump Maintenance

Procedures should be developed for all components according to each manufacturer's instructions. Efficiency tests should be included.

Justification:

Pumps generally are of rugged design and, if the components are greased regularly and the intake valve screens kept clean, function without trouble over long periods. Liquid level control and remote monitoring and control systems should be checked and adjusted as required. Periodic pressure tests should be undertaken to determine decrease impeller efficiency caused by wear.

Maintenance frequencies are typically monthly with pressure tests at one- to five-year intervals according to the solids being pumped.

Guideline 3-31 — Preventive Ventilation Fans and Related Equipment Maintenance

Procedures should be developed for all components of each type of fan and its related equipment and controls. Vibration and, where applicable, acoustical tests should be included.

Justification:

The effective functioning of fans depends on the fan, the operational control system (and the revising mechanism), and the mechanical

louvers or baffles if both or either are installed. All of these must receive appropriate maintenance and be tested for correct functioning in concert.

In addition to routine lubrication and adjustments (including belts where these drives are used), fans should be periodically test run to check for undue vibration from out-of-balance fan blades or nonfunction of the mounting damping devices. The tests should include checks for undue noise and of the condition of sound proofing material. Typically lubrication, general inspection, and adjustment are performed monthly, and testing every 6 months to a year.

Guideline 3-32 — Inspection of Pumps and Fans

Periodic inspection and testing should be undertaken by experienced inspectors to verify that safety and alarm devices are operable and in good condition, and also that machine rooms and equipment are clean and equipment and walk areas are free from excess grease and oil.

Justification:

The safety devices assume considerable importance in emergency situations such as flood and fire. The fact that the situation may rarely arise tends to lead to the neglect of this inspection with the result that the devices are inoperable when needed.

The rational for achieving cleanliness in equipment and rooms was discussed in Guideline 3-28.

LIGHTING

Maintenance of a lighting system in a subway complex comprises cleaning, relamping, and in fluorescent systems, replacing the ballasts. The first

two items constitute the bulk of the work. Lighting systems vary among transit properties, and inevitably any one property will have two or more lighting types and details.

The lamps may be incandescent or fluorescent and can be installed bare with or without reflectors, or covered also with or without reflectors. Any of these variations will affect the effort and cost to maintain the lighting.

Factors to be considered in determining maintenance procedures and schedules must include an assessment of the loss of lighting intensity over the general area of illumination, because of burned out lamps and because of reduction in lighting efficiency by lamp depreciation and dirt on lamps and fixtures. "More Light with Less Manpower," Maintenance Guide for Commercial Buildings, discusses these aspects and provides useful examples for the evaluation of alternative approaches to relamping and cleaning.

Guideline 3-33 – Maintenance of Lighting System

Procedures and schedules for replacing lamps and cleaning lamps and fixtures should be established by an economic study integrating these subjects.

Justification:

The cost of maintaining a lighting system is significant. Lamps, particularly fluorescent ones, loose their efficiency as the service life increases. The effective illumination is also reduced by buildup of dirt on lamps and lenses. Replacement of lamps may be on a scheduled group basis or on a burn out basis. The economics of both methods and of cleaning are discussed fully in Maintenance for Commercial Buildings "More Light with Less Manpower." The document also describes methods for evaluating the alternatives.

ARCHITECTURAL FINISHES

Both for safety and a good appearance, the architectural items and finishes of a transit station must be kept in good repair. As noted in Section 2, this involves both nonscheduled and scheduled maintenance. Generally, the former consists of day-to-day repair of damaged materials and items, and the latter consists of periodic replacement and refurbishing of larger, more general areas of walls, floors, ceilings, etc.

Because of the many variations in materials and application systems now used in existing transit properties, the following guidelines are limited to general principles for repair and replacement rather than covering specific items.

Guideline 3-34 — Type and Cause of Damage or Defect

It is recommended that during maintenance inspection the type of damage or defect and its cause be recorded and analyzed before the repair is made.

Justification:

This guideline is directed not only toward effective repair but also toward preventing recurrence. Table 3-1 shows some usual types of damage that occur to architectural items and trends in the causes of damage. Possible causes for any of the different types of damage have been indicated, but this does not mean that they would apply for any particular item at any particular time. The exception is "wear and tear" which is a function of time, quality, and use.

In general, damage causes 1 through 8 effect damage types A through D and, in some cases, F; these usually require nonscheduled maintenance. Cause 10 effects damage types E and F and generates scheduled maintenance requirements.

Guideline 3-35 — Recording and Remedial Measures for Nonscheduled Maintenance

Suitable forms should be prepared for recording type of damage, cause of damage, and recommended remedial measures. Forms that permit transferring data directly to computer punch cards for computer recording are recommended for rapid retrieval of historical information.

Justification:

Table 3-2 shows the essential portions of such a form for manually recording for floors. The appropriate damage and cause factors from Table 3-1 have been used, and the results of a typical inspection are shown. Using such a form provides both identification of the damage and a historical record for tracing the success or failure of the remedial measures.

Table 3-1

TYPES AND CAUSES OF DAMAGE

Item	Damage						Cause									
	A Cracks	B Chips	C Loose	D Uneven Surface	E Discoloring or Bad Appearance	F Paint Breakdown	1 Structure Cracking	2 Water Seepage	3 Faulty Sub-Base	4 Faulty Support	5 Defects in Material	6 Thermal Movements	7 Mechanical Damage	8 Vandalism	9 Corrosion	10 Wear and Tear
Floors							X		X		X	X	X			X
Stairs									X		X		X			X
Walls																
Applied on Structure							X	X	X		X	X	X	X		X
False										X	X	X	X	X	X	X
Ceilings																
Applied on Structure							X	X	X		X	X				X
Hung								X		X	X				X	X
Doors											X			X		X
Glass										X		X	X	X		X
Escalator and Stair Trim Railings, etc.										X	X		X	X		X

Table 3-2

RECORDING AND REMEDIAL MEASURES
FOR NONSCHEDULED MAINTENANCE FOR FLOORS

Material	Location	Damage					Cause						Remedial Measure
		A Cracks	B Chips	C Loose	D Uneven Surface	Other	1 Structure Cracking	3 Faulty Sub-Base	5 Defects in Material	6 Thermal Movements	7 Mechanical Danage	Other	
Quarry tile	A.5	X						X					Replace in epoxy mortar
Quarry tile	A 17-21			X						X			Replace providing expansion joints indicated. Use Latex cement mortar.

Date inspected _____
Inspector _____
Repair made _____
Foreman _____

Guideline 3-36 — Repair of Finishes Applied Directly to Structure

Where floor, wall, or ceiling materials are applied directly to the surface of a structure and the structure cracks and damages the finish, the following remedial measures are recommended:

- Monolithic terrazzo — If it is necessary to replace the panels between the dividers, the panels should be cut out and an adequate bond breaker or membrane provided between the structural surface and the new terrazzo panel. If thermal movements cause the cracking, plastic divider strips should be used instead of metal ones.
- Tiles (including paving blocks and similar units) — If cracking stems from structural causes and the cracks appear reasonably static, the damaged floor material may be cut out and reset in a plastic organic mortar that can accommodate any subsequent cracking movements. However, if the cracks appear to be "live," the sub-base should be removed, a bond breaker placed on top of the structural concrete, and a wire reinforced sub-base provided. A plastic organic mortar may also be used for setting the finish.

- Tiles and other glazed finish units (wall and ceiling) — The cause of and remedy for wall and ceiling tiles cracking from structural causes are similar to those described for floors. Normally, a sub-base is not placed between the structural surface and the tile, so in this case (if the cracks are not "live") it is probably sufficient to reset the new tiles in a plastic organic mortar. Otherwise, a relatively thin (three-quarter inch) wire reinforced sub-base may be used separated from the structure concrete with a bond breaker and tied to it with flexible inserts. This technique will prevent movements from being transmitted from the structure to the finish. The effect of the increased thickness of the sub-base, however, should be considered in designing the details.
- At entrances and other situations exposed to the weather, materials and procedures for repair may have to be modified (from interior situations) to attain performance that will be satisfactory under the conditions of extreme temperature changes, moisture, sunlight, etc.

Justification:

The above recommendations will correct the principal causes of cracking and spalling in floor, wall, and ceiling tiles and other architectural materials that are affixed directly to the structure. They are also generally effective in preventing thermal cracking within the finish material itself. For the mostly pedestrian wear imposed, subway station floors do not require high strength from the tile mortar; plasticity is desirable.

Guideline 3-37 — Repair of False Walls and Hung Ceilings

Where damage is caused by dampness and metal corrosion, not only should an attempt be made to correct the seepage or dampness through the structural wall, but measures also should be taken to provide adequate ventilation in the air space, and all metal fittings that are subject to corrosion should be replaced with properly protected metal.

Justification:

An underlying cause of deterioration is lack of ventilation between the structure and the finish material. Adequate ventilation will vastly reduce damage. Some methods of providing good ventilation include allowing space between the wall and floor, wall and ceiling, and ceiling and structural wall. Such details are discussed further in Section 5 of the Rapid Transit Subways - Guidelines for Engineering New Installations to Reduce Maintenance.

After proper ventilation is provided, the supporting metal framework should be galvanized or otherwise protected. Additional protection is recommended in the form of epoxy coating for the fixings that secure the framework to the concrete structure. Alternatively, stainless steel could be used for the framework.

Guideline 3-38 – Repair or Replacement of Doors and Glass

If door parts such as closures and latches are frequently damaged, they should be replaced with heavy duty, easily maintainable components. If an all-glass door suffers frequent damage, it should be replaced with a metal door with glass panels for visibility in the upper section only. Decorative glass that is frequently damaged or defaced should be replaced or reinforced with "ripple" glass or plastic.

Justification:

Door maintenance in heavily trafficked stations can be expensive. To reduce the cost, doors with unsatisfactory hardware or excessive glass should be modified according to the recommendations of these guidelines. The additional cost of using the most durable glass available will result in long-range economies. Although most polycarbonates and acrylics (e.g., Lexan, Plexiglas and Acrivue) are shatterproof, they do tend to attract dust, can be scratched, haze, and discolor in time.

Section 4

JANITORIAL SHORT- AND LONG-TERM CLEANING

This section covers short- and long-term cleaning of the stations, the trackways, and the related trackway facilities. The extent of station cleaning depends on a number of variables of both physical and psychological nature. The former category includes the intensity and type of passenger traffic, the station finish material and details, and safety regulations. The latter category relates to the standards set for cleanliness and is mainly for good public relations. These standards determine the amount of effort to be expended on cleaning.

Cleaning of the trackway and its attendant structures depends also on the sources of dirt (train braking system, track ventilation system, debris from passengers, etc.) and the type and sensitivity to dirt of the trains and other equipment operating in the trackway. Except at station platforms, the trackway structures are not public; standards for their cleanliness are determined by technical requirements such as the effects of dirt and dust on train operating equipment, debris clogging the drainage system and causing fire hazards, etc.

CLEANING PROGRAMS FOR STATIONS

A cleaning program should be developed by considering a number of sequential tasks as shown in Figure 4-1. The three major categories of tasks are:

- Assemble data,
- Determine requirements, methods, and schedules, and
- Define organizations.

These tasks and the subtasks indicated in Figure 4-1 are discussed in Guidelines 4-1 through 4-10.

Guideline 4-1 — Assemble Basic Data

For all stations to be included in the program, the following kinds of data must be collected:

- Floor layouts showing all use areas including maintenance equipment and janitorial facilities, floor and stair finishes, and installed equipment including escalators and elevators, agent facilities, staff facilities, equipment rooms, passenger control devices, fare collection equipment, etc.,
- Wall elevations indicating finishes, doors, glass, railings, lights, electrical outlets, ventilation grills, water sources, drains, benches, etc.
- Reflected ceiling plans showing finishes, lights, signs, and ventilation grills.
- System layout key plan showing station locations, entrances, and the major surface street system, and
- Passenger loading per hour during hours of service, train schedules.

Justification:

The information listed above is basic to designing, planning, scheduling, and monitoring a cleaning program.

Guideline 4-2 — Develop Cleaning Standards

Standards of cleanliness must be established for each major item. This is somewhat difficult because appearance is a subjective matter and depends on the item being considered. Standards should be developed to include the following items:

- Floors, stairs, etc. Spot removal of paper and other debris, stains, and spilt material during hours of peak revenue service and a more thorough removal and cleaning after the hours of revenue service; also outside of peak revenue hours, surfaces incurring wear and tear should be restored to original condition

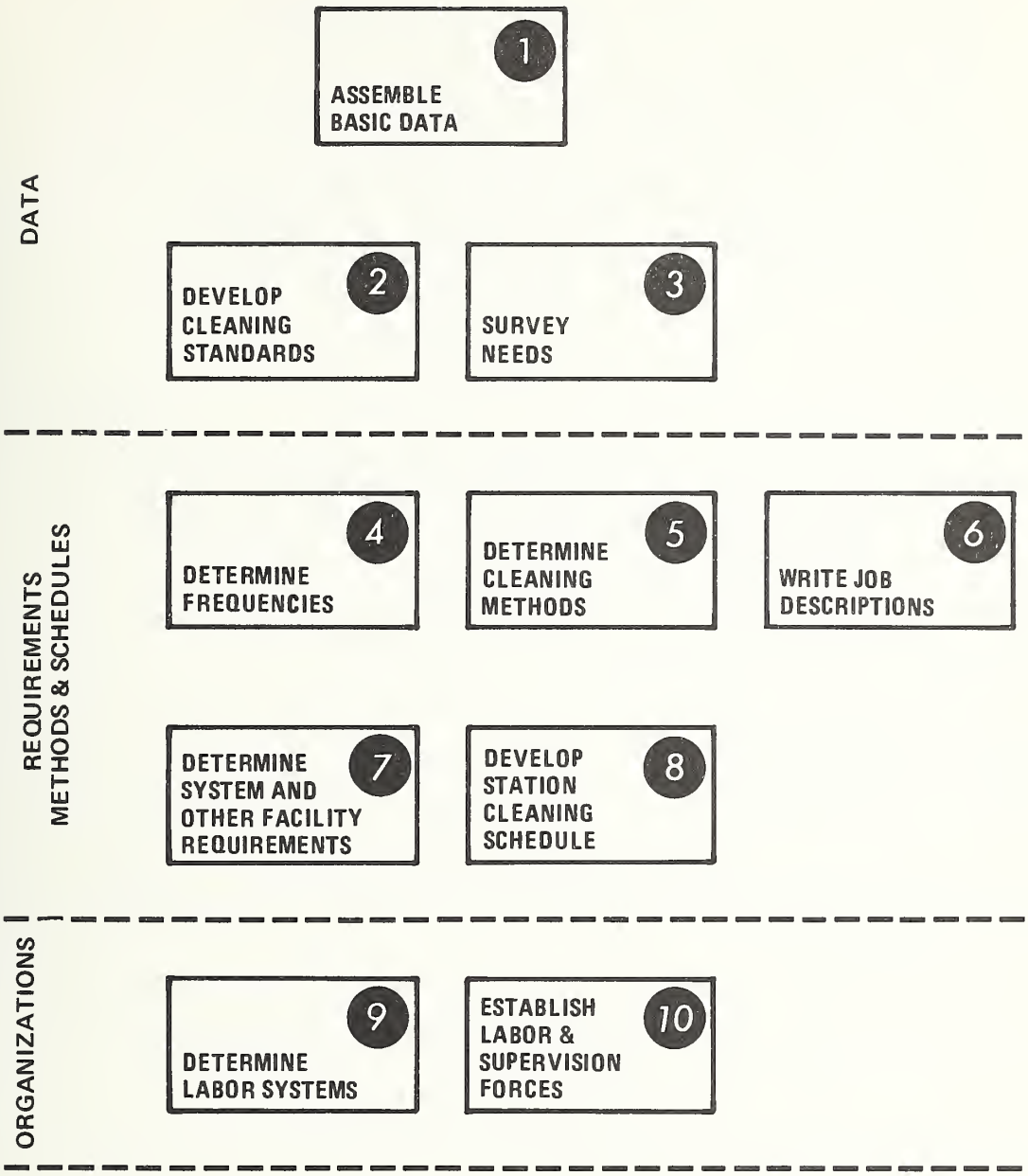


Figure 4-1. TASK FLOW FOR DETERMINING STATION CLEANING PROGRAM

- Walls, doors, glass, etc. Spot removal of fingerprints, graffiti, and other markings and polishing during hours of service; outside of peak service hours, restoration of materials to original appearance,
- Ceilings, lights, and other ceiling fixtures. Dust and stain removal,
- Mechanical equipment including escalators and elevators. Generally the same requirements as for walls and floors, and
- Signs.

Justification:

Establishing these standards provides guidance for succeeding tasks in designing the cleaning program. Standards may be set after a review of the results of existing programs for a particular property as well as of programs for other properties. Standards should also be reviewed frequently and modified as warranted.

Guideline 4-3 – Survey Needs

In general, stations within a system vary in size, layout, passenger loading, and passenger behavior; some stations may be of different ages and finishes. Because of these variations, each station's needs must be surveyed individually.

The following observations should be made to ascertain short-term and long-term cleaning needs.

- During typical week day service:

  The amount of paper and other debris deposited and degree of staining on the floors, stairs, escalators, elevators, and other public areas during at least four periods of the day. According to passenger density, these periods should be either during and after, or after the traffic peaks of morning, midday, afternoon, and late evening.

  Litter receptacle use and adequacy of number and location, and

Walls, doors (and ceilings, if accessible to the public) for defacement.

- During weekend and holiday service, after periods of heavy traffic, record the same data as listed above.
- After daily cleaning cycles, the surfaces of all items should be inspected for appearance and condition.
- At weekly and monthly intervals, surfaces of all items should be inspected for appearance and condition.

Justification:

The information obtained will indicate the degree and extent of policing and short-term and long-term cleaning required for each station.

Guideline 4-4 — Determine Frequencies

By comparing observed station needs to established standards, the appropriate frequency of cleaning can be determined. A schedule for each type of operation should be prepared for each station; an example is shown in Table 4-1.

Justification:

The procedure is necessary both to quantify the operations and to determine job descriptions and scheduling.

Guideline 4-5 — Determine Cleaning Methods

The principle decisions to be made include the extent to which the operations should be mechanized, mobility of equipment to be used, and materials (such as solvents) best suited for the cleaning activity. A cost study should be undertaken to compare various degrees of mechanized operations including any system-wide cleaning requirements (e.g. at-grade stations, offices, shops, etc.). This presupposes that existing union rules can be

made to accommodate mechanization. Other data that must be considered when planning cleaning activities include:

- Policing – Because this is undertaken often during heavy traffic periods, debris pickup and stain removal may be generally limited to manual methods.

  If sweeping of some areas is included, small electric vacuum cleaners may save time.

  Solvents should be available for stain, graffiti, and gum removal from walls and doors.

Table 4-1

CLEANING FREQUENCY SCHEDULE

Station	Item	Frequency in			Remarks
		Times per Day-P[a]	Days-S[b]	Months-L[c]	
Alpha	Floors and other public areas	2	1	3	
	Walls	2	1	6	
	Ceilings	–	–	24	
	Platform Trackway	–	3	(d)	
Beta	Floors and other public areas	1	2	6	
	Walls	1	2	12	
	Ceilings				
	Platform trackway	–	–	(d)	

(a) Policing or spot cleaning
(b) Short-term cleaning
(c) Long-term cleaning
(d) Undertaken by trackway cleaning

- Short-term cleaning — Floors (and other walking surfaces) and walls

  Size of areas to be cleaned

  Kinds of material on surface and whether any method other than sweeping is needed

  Time and labor required for manual method

  Time and labor required for machine method

  Machinery to be battery or cord powered; adequacy of electric outlets available; water supply sources

  Storage facilities for machines and supplies

  Transportation of machines between station levels and between stations versus more machines and provision of storage spaces

  Time utilization of machines

  Special equipment for stairs and escalators

  Methods for removing spot stains and graffiti: mechanized scrubbers versus hand; type of solvents

  Comparative cost analysis of various methods

- Long-term cleaning — Floors (and other walking surfaces), walls, and ceilings

  Size of areas to be cleaned

  Material of surface to be cleaned

  Types and variations of cleaning required for different materials

  Time and labor for manual method

  Time and labor for machine method

  Transportability of machines between stations levels and between stations versus more machines and provision of storage space

  Time utilization of machines

  Special equipment for stairs and escalators

  Comparative cost analysis of various methods

Justification:

Cleaning is a major cost item in the maintenance of a transit operation. It is labor intensive, and quality control is difficult. Determining the optimum method and the extent and type of equipment to produce superior results is, therefore, important.

Guideline 4-6 — Write Job Descriptions

A description of the work procedures for the three different types of cleaning operations (policing, short-term cleaning, and long-term cleaning) should be written.

The essential coverage should include most of the basic items shown in Table 4-2.

Justification:

It is essential that the work to be undertaken and the methods of accomplishing it be itemized so that its duration may be estimated and it may be performed efficiently. It will also be necessary to monitor the results and to adjust procedures as requirements change.

Guideline 4-7 — Determine System and Other Facility Requirements

The underground structures represent only a part of the total cleaning effort for the transit system. Surface stations, shops, offices, and other facilities also require cleaning comparable to that of underground structures. Similar surveys and data gathering should be undertaken of the cleaning requirements of all transit structures and facilities, if this cleaning is to be integrated with that of the stations.

Justification:

The use of the above data is important in determining the most efficient organizations, procedures, and methods for the underground subway structures.

Table 4-2

DATA REQUIRED FOR FORMULATING CLEANING PROGRAM

STATION ALPHA

Item	Data Determination		
	Policing[a]	Short-Term Cleaning[b]	Long-Term Cleaning[c]
Schedule	Days of week, times of day	Days of week, times of day	Days, weeks, months, years; periods of day and week
Areas for attention	Police areas accessible to the public, including escalators and elevators; some service to staff rooms	Sweep or clean all public and staff areas, escalators, and elevators; remove stains and defacements; polish trim	
Items for spot cleaning	To be determined	Floors, walls, seats, etc.	
Work methods	Equipment, materials, and location	Equipment, materials, and location	Equipment, materials, and location
Inspection and reporting methods	Items damaged or requiring repair	Items damaged or requiring repair	
Trash removal	Receptacles to be used	Emptying receptacles; compaction and disposal	
Platform trackway	n/a	If cleaned from platform	
After-cleaning procedures	Storage of equipment	Storage or transportation of equipment	Storage and transportation of equipment

(a) Scope — Inspection, some paper pickup and sweeping, gross stain removal, and damage reporting

(b) Scope — Complete sweeping, trash removal, and damage reporting

(c) Scope — Washing of all areas including floors, walls, ceilings, and architectural trim

Guideline 4-8 – Develop Station Cleaning Schedule

Schedules should be developed that will indicate, in a calendar-time-activity framework, the cleaning requirements for all stations. Input from Guideline 4-6, which establishes the duration of each activity for each station, and Guideline 4-4 will provide most of the data required for developing schedules. A typical framework for scheduling policing and short-term cleaning is shown in Figure 4-2. In this example, policing is assumed to be undertaken during any of all of three 4-hour periods during the main revenue service period and that the short-term cleaning, mainly sweeping, is done after main revenue service hours. Figure 4-3 is typical of a schedule defining long-term cleaning requirements for floors, walls, and ceilings.

Justification:

Properly planned cleaning schedules permit orderly and efficient work operations. Work rosters for every station and for system-wide facilities of like cleaning requirements can be developed in concert with the station schedules.

Guideline 4-9 – Determine Labor Systems

There are several possible systems of undertaking the cleaning: by owner-provided staff, by contract, or by a combination. As in the proposed use of mechanization, accommodation by controlling unions in changing or establishing a labor system must first be gained. Cost benefit studies of these alternative systems should be performed to determine the most advantageous. Such studies should include consideration of the following factors:

- If provided by owner:

  Total number and categories of janitorial staff, including supervisory and administrative,

  Cost of labor, including training and motivating, fringe benefits, absenteeism, etc.,

STATION	TIME	DAYS						
		SUN	MON	TUES	WED	THURS	FRI	SAT
ALPHA	POLICING 0800–1200 1200–1600 1600–2000 CLEANING 2300–0700	T			T			T[a]
BETA	0800–1200 1200–1600 1600–2000 CLEANING 2300–0700							
DELTA	POLICING 0800–1200 1200–1600 1600–2000 CLEANING 2300–0700							

(a) Track cleaning from platform

Figure 4-2. SCHEDULE FOR STATION POLICING AND SHORT-TERM CLEANING

STATION	ITEM	DAYS	TIME	AS SCHED	TIME	FREQUENCY
ALPHA	FLOORS WALLS CEILING	MON-FRI THU FRI	2300–0700 1200–1600 2300–0700	SUN	0800–1600	WEEKLY MONTHLY BIANNUAL
BETA	FLOORS WALLS CEILING					
DELTA	FLOORS WALLS CEILING					

Figure 4-3. SCHEDULE FOR STATION LONG-TERM CLEANING

Cost of equipment, maintenance of equipment, supplies, shop facilities, and storage, and

Cost of administration, supervision, and other overheads.

- If provided by contract:

  Administrative and supervisor staff needed,

  Cost of contract,

  Cost of supervision, and

  Cost of administration and other overheads.

As well as comparing cost and organization, the study should evaluate the quality effectiveness of the owner and contract methods. Two additional factors that appear to be important are security and unionization. The owner is responsible for security in respect to safeguarding the property (particularly during nonrevenue cleaning periods) and cleaning certain potentially dangerous areas such as the platform trackway. In many cases, security is more effectively controlled when the owner undertakes his own work. On the other hand, union rules may penalize either the owner or the contractor in undertaking certain types of cleaning or related tasks (e.g., changing lamps). It would appear that in any case where policing includes responsibility for reporting damage and duties other than cleaning, it should be undertaken by the owner's staff. The number and size of the stations also will have an important influence on the selection of a particular system.

Justification:

Selection of the best system or combination of systems of cleaning by owner or contractor can produce substantial cost and quality benefits.

Guideline 4-10 – Establish Labor and Supervision Forces

Required labor and supervision can be determined after the foregoing guidelines have been implemented. Guidelines 4-9, 4-7, 4-6, and 4-4 are particularly pertinent.

- Guideline 4-9 – The extent of cleaning undertaken by contract will affect not only the direct labor requirements but the number and grade of supervisors,
- Guideline 4-7 – In many cases integration of some of the subway cleaning operations with some or all of the remaining system facilities produces economies,
- Guideline 4-6 – Duration of the several types of cleaning is established in this guideline and is pertinent to the task, and
- Guideline 4-4 – Frequency of cleaning, as determined by Guideline 4-4, will establish basic labor and supervisory numbers.

Supervision and work teams should be established on a roster basis, and allowances must be made for absenteeism, attrition, and retraining.

Justification:

Organizing and managing a cleaning program requires a clear definition of the labor and supervision force, the responsibilities assigned to each, and the disposition and scheduling. This guideline will make such a definition possible.

CLEANING METHODS FOR STATIONS

As in many of the other maintenance operations, the various approaches to station cleaning will depend upon the variables of a particular transit system, as shown in Figure 3-1. The principal variables affecting station cleaning are: size, materials of construction, density of patronage, and dirt loading.

There is an increasing trend towards mechanization of cleaning, sweeping, washing, and polishing for transit property stations and other facilities.

One problem faced by transit properties is transportation of cleaning equipment. Although the floor area of an underground station may be about the same as that of a typical commercial building floor, the 40 to 100 or more stations are spaced from about a half to one mile (or more) apart, whereas in a commercial building the 40 to 100 floors are stacked vertically with ready elevator access between them. The transit stations are connected by the transit rail and the surface roads; each station usually consists of two levels below the street surface with vertical transportation by stair, escalator, and, sometimes, but not always, by elevator.

Because of the problem of transportation between stations and levels, transit properties have been slow to incorporate mechanized cleaning. However, the transportation problem can be readily overcome in existing properties if mechanized cleaning can be shown to be economical.

The following guidelines for manual and mechanized floor cleaning recommend ways to optimize these methods for short- and long-term cleaning. Walls and ceilings are cleaned less frequently than floors, and manual cleaning, with some equipment assistance, appears to be economical for many properties. Others, however, have mechanized this operation to effect cost savings.

Guideline 4-11 — Manual Cleaning

Floors, Escalators, Elevators, Staff, and Other Nonpublic Areas. The most appropriate janitorial aids for paper pickup and sweeping of the horizontal surfaces are two-wheel dust collectors, janitorial carts, spot stain removers, mops, brushes, and brooms. Washing should be performed with detergent applicators such as wheeled pump sprays, water hoses, and squeegees. Where service elevators are not provided, mechanical aids should be selected and sized for ease of vertical transportation in the station.

As for all repetitive manual tasks, the most appropriate supportive equipment will promote efficient and economical performance of the task.

Walls. Wet cleaning of walls depends on the construction materials of the wall. For hard smooth surfaces, two processes should be used in sequence: the application of a detergent and a high-pressure water spray. Mobile scaffolding should be used for cleaning high walls.

Ceilings. Ceiling cleaning methods depend on the ceiling material and construction. A procedure similar to that recommended for walls is recommended for smooth hard ceilings. The cleaning of solid ceilings may be performed from floor level with high pressure washers or vacuum equipment. Mobile scaffolding may be required, however, for high ceiling cleaning. Ceilings of complex pattern, such as the "egg-crate" type with acoustical material behind (if the latter is adequately sealed) may be sprayed with detergents and then rinsed by high-pressure water sprays. Even with waterproof fixtures, it is not advisable to spray water directly on the lamps.

Justification:

Again, the appropriate equipment will pay dividends in being able to produce efficient and economical methods.

Guideline 4-12 — Mechanized Floor Cleaning

Electric vacuum cleaners are recommended as an alternative to manual sweeping and similarly powered, detergent applying brush cleaners as an alternative to manual washing. In general, providing outlets are spaced at reasonable distances, cord powered equipment is preferred over battery.

Justification:

AC powered equipment is lighter, less expensive in first cost, and cheaper to maintain than battery powered. Suitable equipment is manufactured which is self-propelling, with the operator walking behind. Each piece of equipment performs its respective tasks much faster and more efficiently than the corresponding manual method.

If battery-powered equipment is selected, its weight makes transportation between vertical levels a mechanized operation. It can be moved by elevator, if installed; by escalator, providing care is exercised and the equipment is properly secured on devices that will distribute the load over two or three treads; or by a mobile ramp, which is somewhat cumbersome. Equipment can be transported between stations by street with ramps and winches for loading it onto transportation vehicles, or, possibly, on revenue trains.

Guideline 4-13 — Optimization of Floor Cleaning Methods

It is recommended that an economic comparison be made between the manual and mechanized cleaning methods.

Justification:

Mechanization of floor cleaning methods is justified by economical and better results in commercial and institutional buildings and, also, in subway properties (particularly the newer ones). Bases for evaluation include the following:

- In a subway station, a certain number of areas may have to be cleaned by hand regardless of systems available. These include staff and control rooms, lavatories, and most of the nonpublic space and storage. Stairs, escalators, and elevators are also usually cleaned by hand.

- The capacity for cleaning the large floor areas by machine is about 20,000 square feet per hour, or about five times as fast as one man washing with a broom, mop, and bucket.
- Evaluation of mechanized cleaning must consider the total cleaning schedule of the station and the economics and logistics of transporting equipment between stations to clean two or more stations during one shift.
- The size of the manual team required to clean the areas of the station that cannot be mechanically cleaned should be established so that this manual work can proceed in concert with that of a mechanized cleaner. The manual team and the cleaner would then be transported at the same time to the succeeding stations. These methods must be optimized separately for short-term and long-term cleaning on a system-wide basis.

Guideline 4-14 — Trash Collection and Disposal

Alternative methods of trash collection and disposal should be given careful consideration.

Justification:

Several pertinent factors should be considered before designing the trash collection program, including the following:

- The volume of trash and debris collected will vary tremendously among different properties and individual stations. Experience indicates that it may be between 0.5 and 2 pounds per day per 100 square feet; i.e., 200 to 800 pounds in a station of 40,000 square feet.
- Trash may be disposed of daily or at other intervals, but, in any case, a refuse holding room is required where the material may be bagged or baled after collection. Alternatively, properly designed readily transportable bins may be satisfactory.

- A trash compactor may be economical because it reduces the holding space requirements and allows longer periods between disposal. However, compacted garbage is a heavy unit, perhaps 200 pounds, and would require an elevator, with at least hand trolleys for transportation to the surface (or platform if disposed by rail)

Guideline 4-15 — Trash Collectors

Trash collectors and ash trays, in areas where smoking is permitted, for public use should be located conveniently throughout the station including entranceways, mezzanines, and platforms.

Justification:

Observations in the number of properties visited during this study indicated that frequently these collectors were too few and not conveniently at hand. For a modest cost, additional collectors would have prevented appreciable litter being deposited on the floors.

Guideline 4-16 — Public Relations

It is recommended that an educational program should be directed at the public to keep "their" stations clean. Such a program should include:

- Posting notices requesting their assistance and pointing out the cost to the public of cleaning, the difference in appearance of a clean and of a litter-covered floor, etc.,
- Highlighting and conspicuously signing the positions of the litter receptacles,
- Where practical, making the cleaning operations apparent to the public. Such would include uniformed cleaning officials and attendants and undertaking certain activities, such as spot cleaning and the repair of damaged material, in full view of the public.

Justification:

Experience in some of the properties visited indicated that this was a very worthwhile effort, both in reducing the amount of litter deposited and graffiti generated. The consensus between two or three properties appeared to be that "graffiti begat graffiti" and "refuse compounded geometrically with time." In other words, the faster undesirable situations are corrected, the less likely is their recurrence.

CLEANING PROGRAMS – TRACKWAYS

The sequential tasks for developing a trackway cleaning program are indicated in Figure 4-4, and the approach is similar to that described for the station cleaning program.

Guideline 4-17 – Assemble Basic Data

The data should include:

- System underground trackway layout and structural cross sections, including sections through stations,
- Description and location of all wayside and other train support equipment, including cables and lights,
- Arrangement and details of trackway drainage and disposal system, including location and capacity of pumping stations,
- Location and capacity of water supply and hydrants, and
- Sources and types of dirt loads, including metallic dust from train brake and wheel action and rail grinding; ventilation shaft locations.

Justification:

Such information is needed to determine the type of cleaning methods and the capacity of equipment needed.

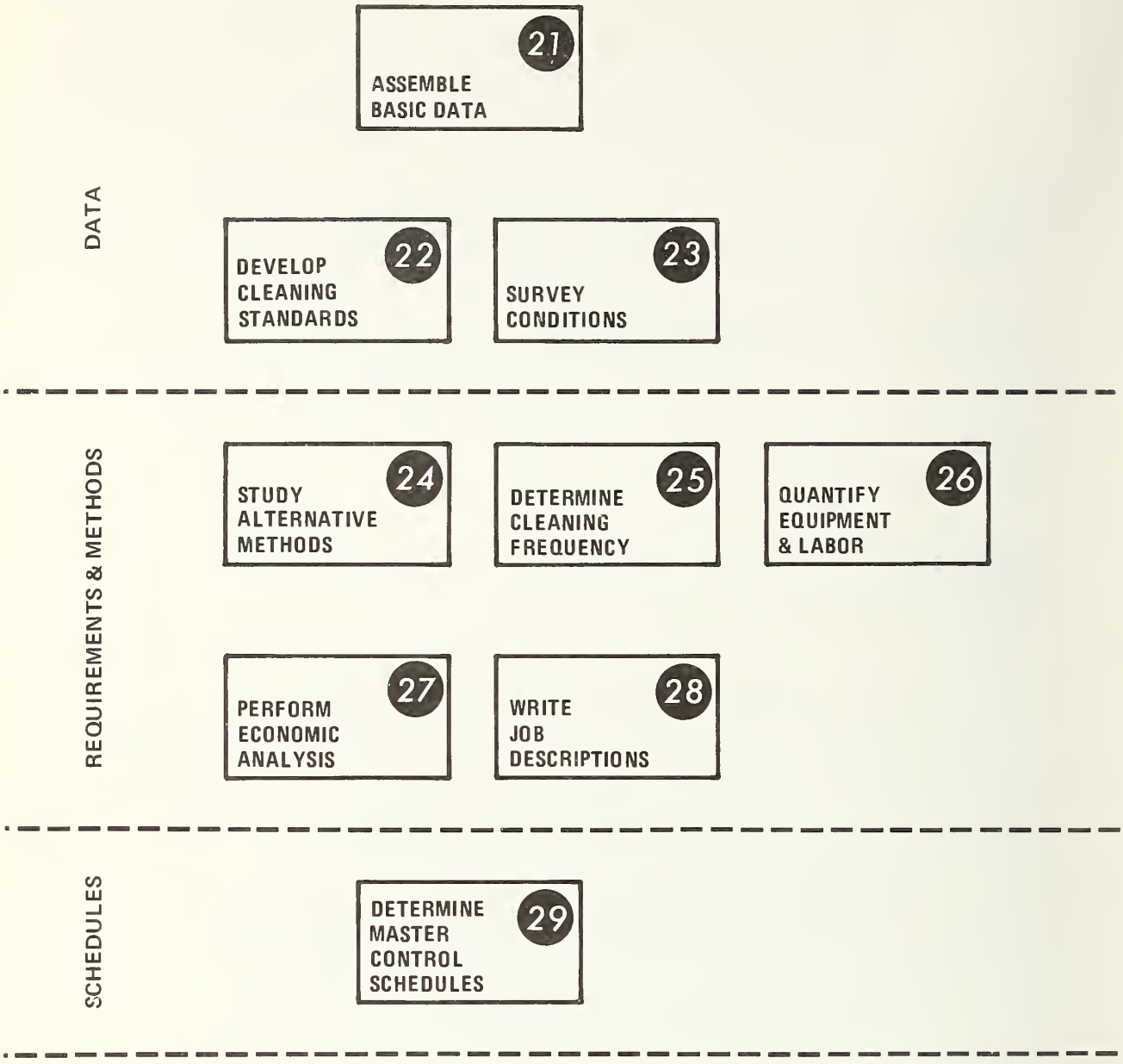


Figure 4-4. TASK FLOW FOR DETERMINING TRACKWAY CLEANING PROGRAM

Guideline 4-18 – Develop Cleaning Standards

To develop these standards requires a technical appraisal of the effects of the accumulation of dust and dirt on the train, on the fixed equipment in trainway, and on safety and health. The influence upon appearance will be a subjective evaluation.

The technical appraisal should be based on the following investigations:

- The effect of metallic or other dust buildup on the train and track control equipment,
- The degree of flammability of dust,
- The incidence of clogging of drainage systems because of dust and garbage,
- The effect of combined dust and moisture on (1) the longevity of timber ties, and (2) the insulating properties of the track support system (when used as negative power return (3) contact rail insulators (not a factor in breakdown of insulation properties in the properties visited),
- The air pollution from airborne dust or the results of metallic oxidation, and
- The effect of dust and debris on the trackway ventilation system.

The visual effects of debris lying on the trackway should be assessed. The trackway walls and ceilings should be included if they are not covered by the station cleaning program.

The results of the investigations of any of the above "technical" items may indicate one cleaning standard that will satisfy all the requirements of the above items, or separate standards for individual items may have to be established. A separate cleaning standard should be produced for the station platform trackway.

Justification:

Such standards will guide the design of the cleaning and equipment program.

Guideline 4-19 — Survey Conditions

Dust and dirt buildup will vary in degree along the trainway according to several factors. These variations will be emphasized in transit systems that operate lines of different ages, equipment, and schedules. The trackways should be surveyed at specific intervals along the routes to gather the following data:

- The extent and density of dust buildup on the equipment and other items in the trackway should be measured,
- Samples of the dust should be obtained for analysis,
- Where possible, any obvious dust or debris sources should be identified, and
- The condition of electrical and communication cables, lighting fixtures, or other equipment that might be sensitive to water must be identified.

Guideline 4-20 — Study Alternative Methods

A selection of the most effective method(s) for cleaning the trackways of a particular transit property will be influenced by the general and technical variables indicated for "Trackway Cleaning System" in Figure 3-1, as well as the specific technical data noted in Guidelines 4-18 and 4-19.

An economic cost analysis should be made of data obtained from a technical evaluation of alternative cleaning methods (see Guideline 4-23). Alternative methods include:

- Cleaning by wash trains,
- Cleaning by vacuum trains,
- Washing manually,
- Cleaning the platform trackway with vacuum equipment operated from the platform,

- Mounting vacuum equipment on rail, and
- Removing debris manually.

These methods are indicated in Figure 4-5. It will be noted that Alternative 3 is used with Alternative 2; other combinations are also possible.

Justification:

The study will reveal the comparative effectiveness of several possible cleaning alternatives for specific trackway conditions.

Guideline 4-21 – Determine Cleaning Frequency

It is recommended that the frequency of cleaning operations be estimated with the alternative methods. For this undertaking, it is important to consider the following:

- The effects of long-term dust buildup in an existing system (hitherto not, or ineffectively, cleaned),
- The possibility of dirt accumulation being changed in the future by reason of the introduction of new equipment, or other items, and
- Restraint on the efficiency of cleaning methods by introduction of new equipment in the trackway, including automatic train control and other sensitive equipment.

Justification:

The determinations of the time intervals between the possible cleaning methods is an essential part of the ensuing economic study.

It may be anticipated that all systems, sooner or later, will purchase new rolling stock which may lessen the dirt loading (e.g., dynamic braking system). However, this may be more than offset by the installation of more sensitive control equipment which may not be so tolerant of metallic dust. Also, rail grinding operations may be modified to affect the dust load.

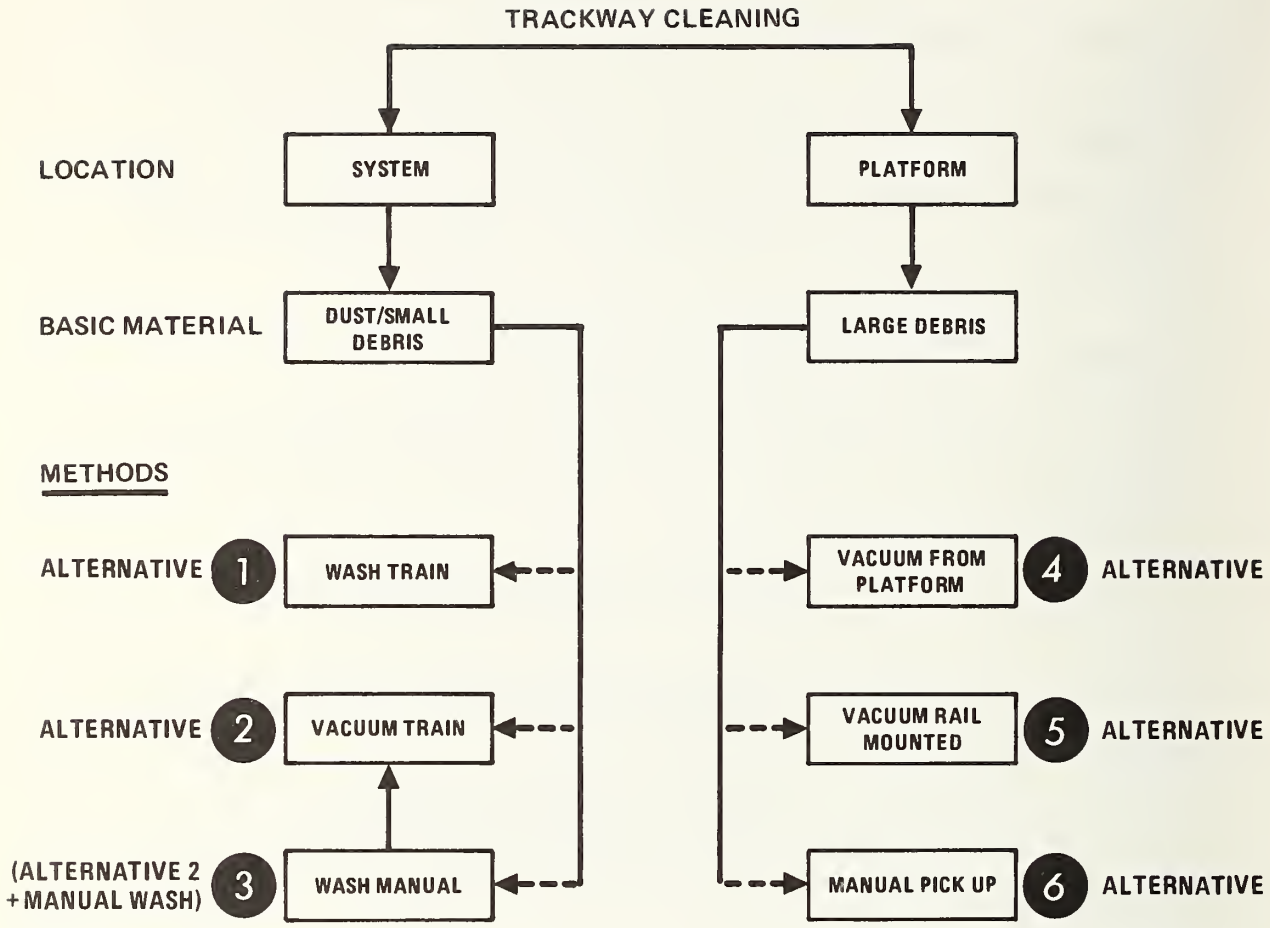


Figure 4-5. ALTERNATIVE TRACKWAY CLEANING METHODS

Guideline 4-22 – Quantify Equipment and Labor

It is recommended that the equipment and labor be quantified for each of the alternative cleaning methods. For the quantification, the following factors should be taken into account:

- Train schedules and allowable periods of likely track occupancy; where service occurs 24 hours per day, a single track revenue train may be required,
- Frequency of required cleaning,
- Utilization of the equipment,
- Power requirements, and
- Labor requirements.

Justification:

This is a further essential step to gather data for the economic analysis.

Guideline 4-23 – Perform Economic Analysis

It is recommended that a comparative economic analysis be made among the alternative systems. The following should be considered:

- Equipment, including maintenance, repair, and facilities for service and storage,
- Materials and supplies, including power, oil, detergents, etc.,
- Labor cost evaluation also on present worth cost basis, and
- Support facilities and tasks; i.e., water, debris disposal, preparation for cleaning.

Justification:

The analysis should provide the information required to select the most appropriate and economic methods for trackway cleaning. In arriving at a decision, account must be taken of whether the use of a particular type of equipment can be extended to the at-grade track and yard track sections of the system.

Guideline 4-24 — Write Job Descriptions

It is recommended for the methods selected, job descriptions including equipment operating procedures be established. It would be expected that quantitively the jobs within the same methods would vary along the route according to the distribution of their dirt load.

Justification:

In this undertaking, the components of each of the selected cleaning methods are placed on a labor-equipment-time framework. This should produce a detailed description for the performance of tasks to enable the development of job rosters, and to provide input for overall schedules.

Guideline 4-25 — Determine Master Control Schedules

It is recommended that a master schedule be developed which will show, on a cyclic time basis, the distribution of the cleaning resources for the methods to be employed.

This will require integration with the scheduling of many other trackway operations which, in turn, are constrained by the revenue schedule of the trains. Other trackway schedules include those for

- Track, power, and communications maintenance,
- Structures and support structures, and
- Equipment maintenance.

In addition, the integration of some station cleaning schedules may affect some items in the "Method Schedule."

Justification:

The schedule will provide the means for the orderly and economic programming of the trackway cleaning.

Section 5

MAINTENANCE AND CLEANING ORGANIZATIONS AND OPERATIONS

An efficient organization for the maintenance and cleaning of the subway structures requires the following principal areas of responsibilities:

- Overall management, direction, and coordination,
- Engineering inspection, planning, design, and scheduling,
- Management of the works, work shops, and field maintenance, and
- Field maintenance by work forces who perform the actual maintenance, replacement, and cleaning.

The composition and functions of the first two areas in general principal are similar for most properties; the responsibilities for management of works and the composition of field maintenance will vary considerably according to the extent of the maintenance work that is contracted outside. Figure 5-1 indicates the portions of a typical transit organization that relate essentially to the maintenance of the structures. This organization is representative in general form of the organizations of many of the properties visited — see Rapid Transit Subways — Maintenance and Engineering Report.

SECTION A OPERATIONS

The train and station operations (Section A of Figure 5-1) can be considered the revenue producers of the property and must be the principal considerations in structuring maintenance operations in the stations and trackway. The schedules of maintenance activities for power and signals and track (which are excluded from this study), together with maintenance of structures, will be coordinated with train operations

through system-wide scheduling. The cleaning coordinator will integrate the activities of station maintenance with station operations. In most properties, train operations control the track transportation for structure maintenance, particularly when revenue service is provided around the clock.

SECTION B PLANT MAINTENANCE

Section B of Figure 5-1 includes all controls and activities for subway maintenance that is within this study's specific concern. However, there are two approaches that may govern the organization of field work: centralized maintenance and area maintenance, as illustrated in Figures 5-2 and 5-3. The principal difference in the two concepts is that in the centralized system the work is controlled from one crafts body (in this case from workshop services), and in the area system the primary control is from the work maintenance manager's office.

The centralized system is essentially one of specialization where craftsmen, in groups, undertake maintenance of the entire system. In the alternative approach, the system is divided into small work units, the maintenance of which will become the responsibility of one or several men depending upon the type and complexity of the work.

For rapid transit structures (as opposed to other facilities, such as buildings) it appears that both approaches may be used advantageously according to the type and nature of the maintenance. Generally, the maintenance or refurbishing of structures and finishes is centralized as are periodic and long-term maintenance of mechanical and electrical equipment. Long-term cleaning may also be conveniently centralized. For policing activities, the area approach is widely used and sometimes can be combined with short-term cleaning.

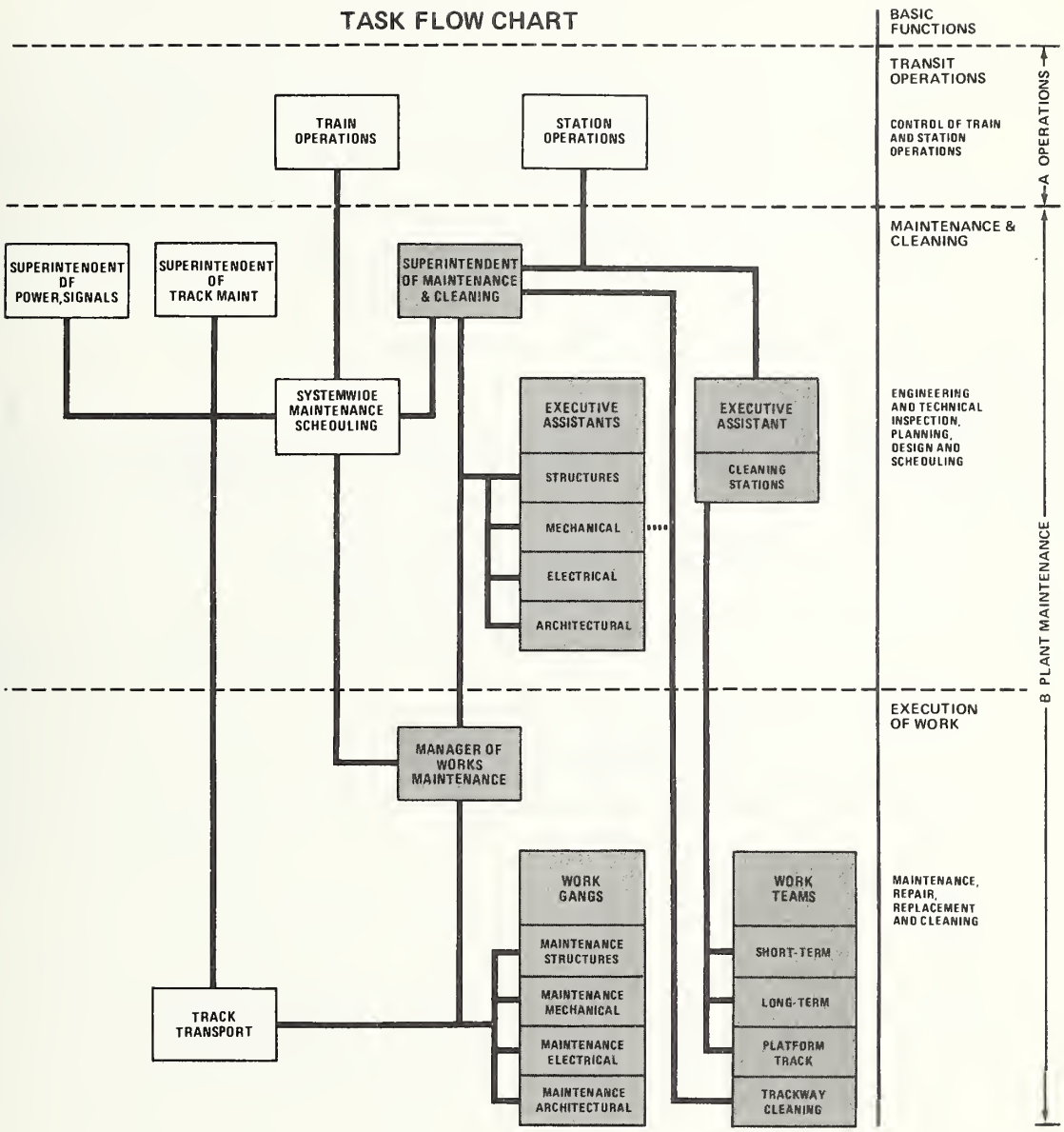


Figure 5-1. FLOW CHART OF MAINTENANCE AND CLEANING ORGANIZATIONS AND OPERATIONS

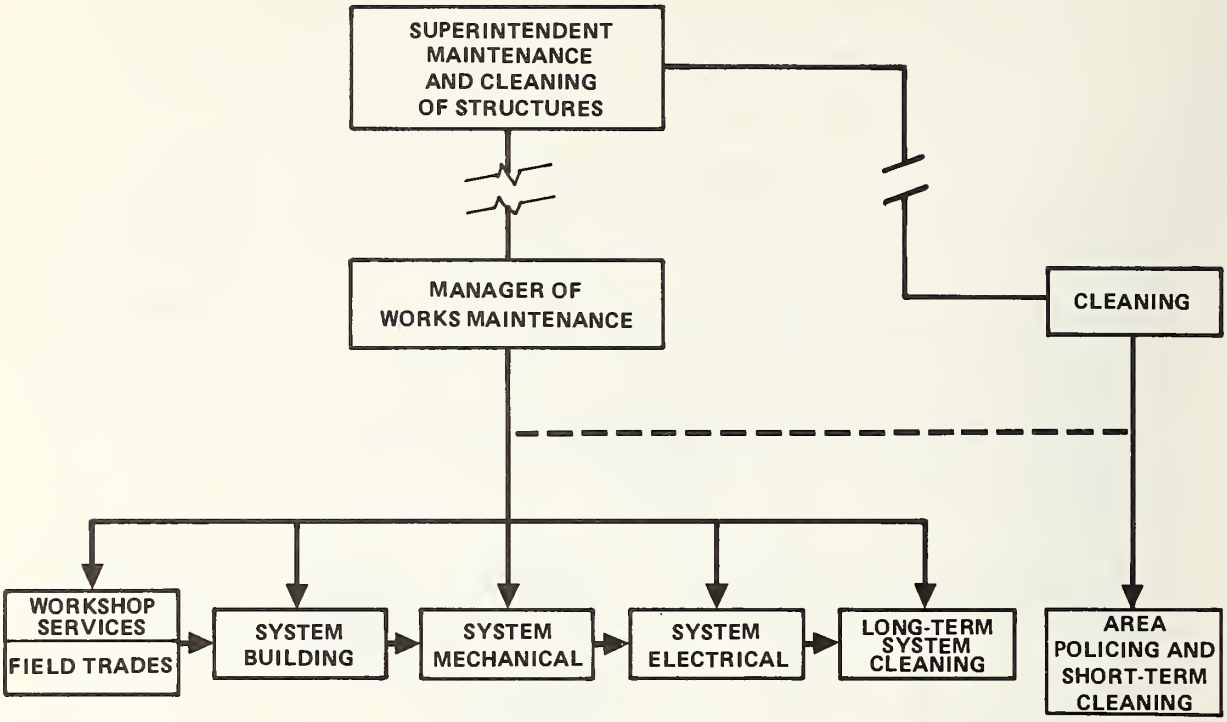


Figure 5-2. SERVICE ORGANIZATION FOR CENTRALIZED MAINTENANCE

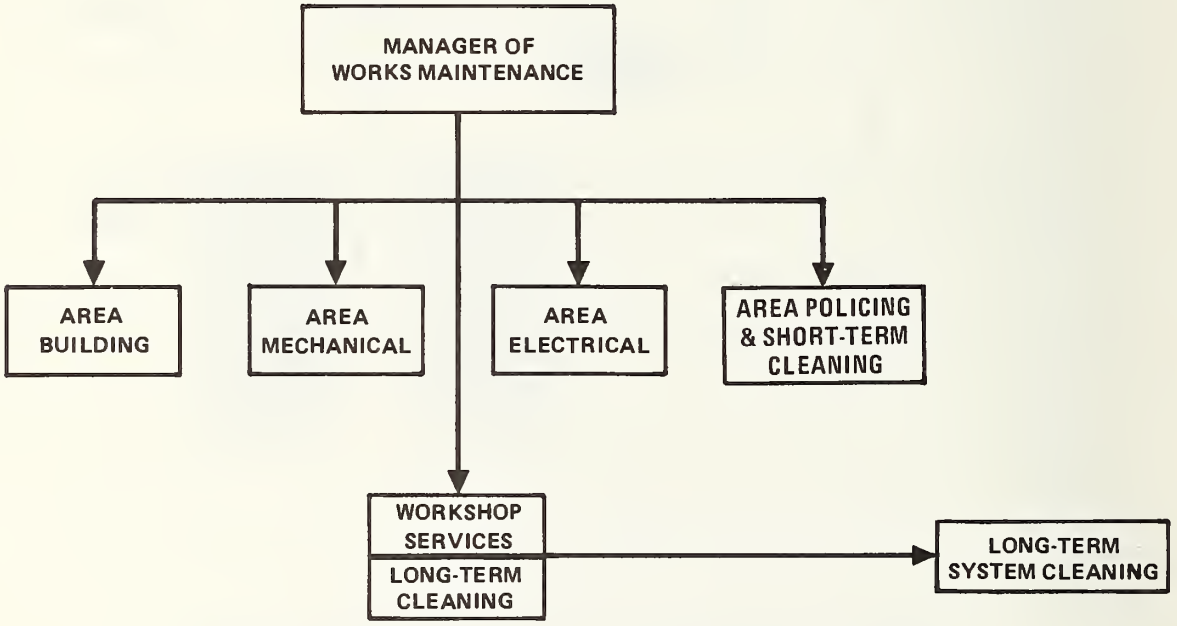


Figure 5-3. SERVICE ORGANIZATION FOR AREA CLEANING

The following guidelines cover what are considered the more important aspects of the management organization and the maintenance operations. The labor and site supervision of these operations are not included as these are usually straightforward standardized work practices.

Guideline 5-1 — Maintenance Organization Chart

It is recommended that a maintenance organization chart be established. During initial development, the chart should indicate the principal administration and the key control positions, the disciplines, the crafts, and the type of maintenance as well as the other interacting maintenance operations.

Justification:

This chart will provide the basic framework for the subsequent tasks of developing job descriptions, methods, and systems. Figure 5-1 is a chart that might be suitable for this purpose for some transit systems.

Guideline 5-2 — Superintendent of Maintenance Structures

For maintenance of subway structures, the function of a superintendent of maintenance of structures should be established. The superintendent should be a senior level engineer with broad experience in transit engineering and maintenance.

Justification:

The superintendent is responsible for all subway structure maintenance which may represent an appreciable portion of the property's annual operating budget. The efficient direction of this operation is, therefore, an important economic consideration.

Guideline 5-3 — Control and Design of New Works

It is recommended that the superintendent of maintenance advise on both new work and replacement items. He should also approve such designs and specifications prior to their implementation.

Justification:

The superintendent, from his historical experience of the performance, maintenance, and cleaning of the structures, finishes, and mechanical and electrical items that compose the subway system, can provide valuable economic and performance input for the design and specifications for replacing elements of the system and for the installing new work.

Guideline 5-4 — Executive Engineering Assistants

It is recommended that executive engineering assistants to the superintendent become part of his organization. The disciplines should include structures, mechanical, electrical, architectural, and cleaning.

Justification:

This is a requirement for optimizing the maintenance operations. Executive assistants from the engineering and architectural disciplines should be responsible for inspective maintenance and monitoring, developing repair and replacement designs and specifications, planning and scheduling, administering contracts (if work is contracted), and office site inspection (such as checking and clarifying engineering requirements). Performance record-keeping should be considered part of these responsibilities.

According to the size of the property, the assistants may be assigned either part-time or full-time to the maintenance organization. In the former situation, the other part of their duties will be with new works.

Guideline 5-5 — Executive Cleaning Assistant

It is recommended that an executive assistant for the function of cleaning be included in the superintendent's organization.

Justification:

The function relates to the control of the various cleaning activities within the station areas. Cleaning accounts for a substantial part of the total structure maintenance budget; it is labor intensive and its scheduling is complex. Cleaning requirements will vary among the individual stations of a system and will change with changes in patronage. Optimization of cleaning activities requires the services of an appropriately qualified administrator.

Guideline 5-6 — Manager of Works: Maintenance Function

It is recommended that this function, as it often does, include direct control of the workshop and field maintenance operations.

Justification:

There are several distinct advantages of closely integrating the workshop and field operations, such as:

- Unscheduled or emergency maintenance (repair) can be undertaken in the workshop by the workshop trades whose base workload is routine maintenance of items and components,
- Many routine field maintenance activities such as servicing mechanical equipment may be economically undertaken as part-time duty by the workshop trades, and
- It may be convenient for the workshop administration to be responsible for all surface (or surface rail) transportation for maintenance requirements.

Guideline 5-7 — Track Transport

It is recommended that operation of track transport for maintenance supplies or garbage disposal be a responsibility of the superintendent of train operations. (An exception to this is sometimes, when properties shut down service for a reasonable duration, weekdays, or weekends.)

Justification:

Safety, an overridding consideration, is best achieved by placing control of the maintenance work trains under "train operations," the organization most experienced in all train safety procedures.

Guideline 5-8 — Trackway Cleaning

It is recommended that the trackway cleaning train be controlled by train operations.

Justification:

The advantages are basically the same as those given in Guideline 5-7.

Guideline 5-9 — Implementation of Maintenance Systems

It is recommended that studies, including economic, be undertaken on the alternative systems of owner versus contract work forces to select the most effective for a specific property.

Justification:

Examination of Figure 3-1, Group D, shows that numerous variables affect the maintenance operation and organization. The decision to perform maintenance with any alternative requires studying and analyzing the impact of all variables within a particular transit property. Some general comments are included here about the relationship among the source of variables and other factors and their effect on the choice of alternatives.

- The age and size of a property influence the quantity of work to be undertaken. If a property has been in service long enough to need general replacement of its architectural finishes, the most economical method is probably to let a contract for replacement. An exception might be station platform trackway walls or ceilings that would be hazardous locations for contractors.
- Unionization may create problems in some alternatives and may make others attractive. The unions may be sufficiently restrictive in trade work that it may be uneconomical for an owner to retain certain crafts to do small amounts of work over intermittent periods; contracting the work is an obvious solution. However, if the owner has restrictive union agreements where a few crafts can perform all the trade work required in structure maintenance, it might be profitable for the owner to handle all small maintenance projects with his own forces.
- Train schedules, the presence of sensitive communications equipment, the power conductor rail, transportation, and accesses are factors that usually make the owner decide to undertake his own trackway maintenance.
- Some work that requires a high degree of specialization may justify the exception of hiring an outside contractor. An example of such work is grouting of soil or of the concrete structure.

Guideline 5-10 — Implementation of Cleaning System

To select the most effective and economic type of cleaning maintenance for a specific property, both owner and contractor systems should be evaluated.

Justification:

Referring again to Figure 3-1, the same general comments about variables are applicable as they were for Guideline 5-9. The following are also pertinent:

- Where unions allow, the owner may advantageously expand certain types of janitorial operations to include other duties (this possibility will be discussed further in Guideline 5-11).

- Because of the competitive nature of the contract system (especially when the contracts are reviewed at regular intervals), the contractor has greater incentive to motivate his labor than does the owner.
- As the size of a property increases, it becomes more difficult for the owner to properly supervise and motivate his cleaning force. This fact also makes the contractor system more favorable.

Guideline 5-11 — Determination of Centralized or Area Work Organization

The alternatives of centralized or area work organization for each of the several types of maintenance should be compared to permit selection of the most economical.

Justification:

Adopting the most appropriate organization, particularly in the case of owner operations, can result in appreciable operating cost savings. Area organization may be appropriate in the following respects:

- The economics of janitorial maintenance are particularly sensitive to its organizational structure. The work is monotonous, but if it is interspersed with other duties or if the work location is varied, the monotony can be alleviated. Other duties could include opening and closing stations, starting escalators after emergency stops, lamp maintenance, etc.
- A sense of pride and fixing of responsibility may be developed if one or two men are responsible for the overall appearance of individual stations, particularly if they are responsible for short-term cleaning as well as for policing.
- Time and cost of getting to work may be reduced by using labor from the locale of the work area.

An area organization may effect cost benefits for maintenance of mechanical equipment for the following reasons:

- The mechanic will become more knowledgeable of the condition of the equipment for which he is responsible,

- Competition may be engendered among areas regarding the reliability of equipment,
- Cost and travel time may be reduced by employing local staff, and
- Emergency breakdowns may be corrected more expeditiously.

Additionally, in both janitorial and mechanical types of maintenance, the area method permits ready identification of responsibility for unsatisfactory work. Drawbacks of the area maintenance concept may include the following:

- Relying on the worker to perform effectively may not always be successful, and supervision may have to be increased,
- Less flexibility in deploying the work force may lead to an overall increase in the labor force for the system.

Guideline 5-12 – Training of Maintenance Personnel

Maintenance personnel should receive periodic instruction and training on subjects pertaining to the maintenance of the underground construction complex. For this purpose, an appropriate organization and facilities should be established and instructors experienced in the subjects to be presented should be appointed.

Justification:

Such instruction and training should be developed for three situations:

- Training new employees for all maintenance sections – Subjects would include work organizations and procedures, specific maintenance techniques, use of equipment and tools, safety rules and procedures, relations with the public, etc.
- Familiarization with the maintenance requirements of new equipment or materials and systems. This would be provided to the personnel of maintenance sections affected by the new installations.

- Updating of existing maintenance procedures – This would include changed techniques and methodology given to the maintenance personnel affected.

Justification:

Maintenance procedures should not remain static if efficiency and effectiveness are to be improved. Desirable changes may become apparent after study by the maintenance engineers of the existing procedures, historical data and records, and with input from the maintenance personnel.

Facilities would include classrooms, teaching aids, such as projectors and viewgraphs, models, and displays. Certain equipment and tools and storage thereof should be displayed. Instructors would be drawn principally from the suitable personnel of the engineering and maintenance sections supplemented as necessary by outside specialists, equipment manufacturers, etc.

Section 6

EQUIPMENT, SUPPLIES, AND FACILITIES

This section provides guidelines for selecting equipment and consumable supplies that a subway property may need to clean and maintain its underground sections. Requirements for maintenance staff and storage rooms in the stations are also included.

The guidelines cover inventorying materials, parts, and supplies for maintenance (repair, replacement, etc.) and cleaning of the subway structures. The necessary support shop facilities are also described. No attempt is made to quantify equipment and materials or to size the supporting facilities because of the vast differences in transit properties. These guidelines can, however, be used for quantification once a maintenance system and methods have been chosen for a particular transit property.

EQUIPMENT LIST

A partial list of typical equipment required by a subway property performing its own maintenance and cleaning work is shown in Table 6-1. The equipment is grouped according to major activities; type, cost, and manufacturer, where available, are provided only for illustrative purposes and none should be considered an endorsement or the best obtainable for a specific purpose.

Guideline 6-1 — Equipment Required for Repair Maintenance of Trackway and Station Structures and Architectural Finishes

After the maintenance system and methods are selected, an equipment list should be developed. For maintenance of items within the trackway,

Table 6-1

MAINTENANCE EQUIPMENT

SECTION A – TRACKWAY					
Item No.	Equipment	Typical Values			Manufacturer/Supplier
		Weight (lb)	Size	Values 1976$	
A-1	Tunnel jumbo road/rail, moveable work Air compressor, lighting generator				International Corp.
A-2	30-ton mobile crane road/track				Pettibone Corp. 47 W. Division St., Chicago, Ill.
A-3	General purpose 2-ton P. T. O. road/track Air compressor off P. T. O.; diesel generator for 300-amp welder and lighting; oxygen/acetylene gas welder	4,000			International Corp.
A-4	Inspection vehicle road/track	1,500		38,000	International Corp.
A-5	Back hoe "speed-swing" 3/4-yd bucket, 3-ton beam				Pettibone Corp.
A-6	Air compressor DR250 (2-wheel trailer incl.)	3,950		12,000	Ingersoll-Rand, Mocksville, NC
A-7	Welder dc 350-amp diesel	3,000	163 in. x 73 in. x 19 in. high	38,000	Miller Electric, Appleton, Wisc.
A-8	Gas cutting and welding (equipment only)			300	Victor
A-9	Drain cleaner electric, 1/2 in. x 100 ft line	116		395	General Wire Spring Co.
A-10	Drain cleaner electric, 3/4 in. x 100 ft line	260		832	
A-11	Plaster/mortar mixer, electric	875		1,600	C. M. C. Waterloo, Iowa
A-12	Sandblasting equipment	230	16-in. dia. 50-in. height	1,435	
A-13	Paint sprayer, 10 gal. (with hose gun)			525	Binks
A-14	Concrete joint saw electric Model CS 801			550	Stow
A-15	Core drilling equipment, 2 to 4-in. cores 2 ft deep, electric, Model 3948/4100			525	Milwaukee Machine

Table 6-1 (Continued)

Item No.	Equipment	Typical Values: Weight (lb)	Typical Values: Size	Typical Values: Values 1976$	Manufacturer/Supplier
A-16	Concrete breaker, 100 cfm JB60 (pneumatic jack hammer)	67		575	Jay Manufacturing Co.
A-17	Impact wrench, pneumatic, 1-in. compactor			500	Chicago Pneumatic Co.
A-18	Caulking hammer, pneumatic				
A-19	Electric drill, #1650, 1/2 in.			85	Milwaukee Machine
A-20	Dial gauge			190	
A-21	Tape extensometer			420	
A-22	Strain gauge, CT-171M-multiposition	53		330	Pacific Scientific Co.
A-23	Thickness gauge, ultrasonic	6		1,750	Branson
	SECTION B – TRACKWAY AND WAYSIDE FACILITY CLEANING				
B-1	Vacuum cleaner "Vac-All" road/rail			40,000	Central Engineering, Inc.
B-2	Vacuum cleaning train				Custom manufacture
B-3	Trackway detergent/wash train				Custom manufacture
B-4	Sump pump, Model 521, 100 gpm at 30-ft head	300		600	Aurora Pump Co., Burlingame, Calif.
B-5	Pressure water washer				
B-6	Hanging scaffold with el. winch				
	SECTION C – MECHANIZED STATION CLEANING EQUIPMENT				
C-1	Floor Sweeper, 580 (ac 110)	110		786	Clarke-Gravely Muskegon, Mich.
C-2	Sweeper, T752, battery	850	41 in. x 49 in. x 38 in.	2,638	Clarke-Gravely Corp.
C-3	Scrubber, TB20E	225		1,320	
C-4	Scrubber TB24 battery	1,040		3,293	Clarke-Gravely
C-5	Mechanical wall and ceiling scrubber				Advance Floor Machine
C-6	Trash compactor				
C-7	Moving scaffold				
C-8	3/4-ton truck (road)			5,800	General Motors

alternatives must be evaluated of purchasing self-propelled road/rail vehicles equipped with the basic compressed air and dc electric tool power sources, movable work platforms, etc., or of developing suitable work trains by mounting the necessary equipment on a flatbed. In the latter case, mobility can be provided by locomotives powered by battery, diesel, or the contact rail.

Justification:

The typical list Section A of Table 6-1 was compiled on the following bases:

- For safety, the trackway maintenance vehicle could be powered by a diesel engine with exhaust scrubbers.
- Power tools used in the trackway should be either pneumatic or electric; power for either may be supplied from motor-driven compressors or generators mounted on the maintenance vehicle or placed at the track side and, in some cases, on the surface. Hydraulic concrete breaks and other items powered by electrically driven pumps are a practical but somewhat expensive alternative.
- Grouting plants for soil and concrete are questionable items because this very specialized work will probably be contracted out in most situations.
- Items A-20 through A-23 are used in inspection and testing and, as discussed in Guidelines 3-3 and 3-11, their use depends on the type, material, and conditions of the structures.

Guideline 6-2 – Trackway and Wayside Facility Cleaning

Section B of Table 6-1 lists the appropriate items of equipment.

Justification:

The equipment was selected after consideration of the following bases:

- Selection of vacuum or wet trackway cleaning is discussed in Section 4; at present the equipment for both methods has been custom manufactured for specific properties; such equipment is described and its use

discussed in Section 3 of the Rapid Transit Subway Maintenance and Engineering Report. With respect to Item B-1, suitable vacuum equipment can be mounted either on the platform or on rails, is suitable for clearing large debris deposited on the trackway, and is commercially available.

- Cleaning ventilation or emergency exit shafts may require hoists for cleaning platforms, ladders, or other aids to access. Cleaning may be accomplished by manual brushing and vacuum equipment in conjunction with high pressure air jets or by manual wet cleaning equipment.
- Trash is usually removed from pump sumps by hand; this could perhaps be more economically performed with a sludge remover.

Guideline 6-3 — Station Cleaning with Mechanized Equipment

Section C of Table 6-1 lists mechanical equipment suitable for mechanized station cleaning. It is recommended that all mechanical equipment be electrically powered and that all floor cleaners and washers be battery powered. Gasoline motors are inadvisable underground; diesel and propane are acceptable but heavy and expensive. If adequate power outlets are available, an ac electric supply for wall and ceiling cleaning is economical and satisfactory.

Justification:

Mechanical floor cleaning equipment is becoming popular with transit owners for the economies it provides against increasing labor costs. Overall, cord powered equipment is preferred over battery powered equipment, because of lower cost and weight. If battery powered equipment is selected, it should have sufficient power capacity for an entire one-shift operation. It is further advisable to have charging equipment built into the machine so that recharging is not a factor of storage location.

INVENTORYING MATERIALS AND PARTS

Maintenance and cleaning operations require a reliable supply of materials and parts available in stock at all times. The following guidelines (6-4 through 6-8) include a checklist for typical items necessary for an average transit operation. Inventorying these items is important to maintain a satisfactory supply.

Guideline 6-4 – Determine Materials and Parts Inventory

Inventories should be made of materials and parts for the maintenance and cleaning of structures, mechanical and electrical equipment, and architectural finishes. This activity should establish minimum and maximum quantities to be kept on hand; the former depends on delivery times and estimated rates of consumption, the latter on the economics of investment, and storage space available.

Justification:

A checklist has been prepared as a guide to the items that should be considered. Maintaining these items at satisfactory levels is essential to an efficient maintenance and cleaning program. The cost of maintaining an inventory may be partly offset by bulk purchasing and as a hedge against inflation. Table 6-2 shows this sample checklist.

The following comments are appropriate to each of the major maintenance areas.

Structures. Tunnel liners, especially precast concrete and cast iron, are expensive to purchase on a unit basis; therefore, during construction a number of rings (including tapers) should be purchased for storage.

Table 6-2

MATERIALS AND PARTS CHECKLIST
FOR FIVE MAJOR MAINTENANCE AREAS

STRUCTURES
Cement and aggregate
Reinforcement
Lumber and form bolts
Structural angles and plate
Precast concrete tunnel linings
High-strength bolts, washers, and grommets
Caulking lead and other material
Sand or shot (for blasting)
Paint: prime coat finish in various colors inorganic zinc for prime and finish
Welding rod – coated
Oxygen/acetylene gas
MECHANICAL AND ELECTRICAL*
Escalator treads, bearings, electric brushes, control components, lamps, brake components, fastenings, hand rails and components, architectural components
Elevator ropes, slides, door control mechanisms, brake components, motor control components, electric brushes, lamps, architectural and door components
Pump impellers, bearings, electric brushes, control mechanism components, liquid level control components, light bulbs
Fan blades, reversing mechanism components, bearings, belts, electric brushes, remote control components
GENERAL MECHANICAL AND ELECTRICAL REQUIREMENTS
Fastenings – bolts and screws
Piping and connectors – collars, elbows, unions

*Standardization in these areas will significantly reduce inventory requirements.

Table 6-2 (continued)

Faucets and components
Grease and oil as required by all mechanical fixed equipment
Conduits and fixings
Cable and wire
Connectors and wire
CLEANING (CONSUMABLES)
Detergent
Solvents and wax sealants
Vacuum filter bags
Trash liners
Manual cleaning tools
ARCHITECTURAL
Floor tiles, pavers, etc.
Tile cements
Other floor material as appropriate
Stair treads, various
Wall tiles
Wall cement
Wall panels
Metal lathe and fasteners
Door hardware including lock latches, hinges, stops, closures, fasteners
Plumbing fixtures and fittings
Sheet metal and ducting
Appropriate fastenings
Paint
Plaster
Glass and glazing materials
Waste receptacles
Signs

Mechanical and Electrical. Escalators, elevators, pumps, and fans may be expected to have useful lives of 50 years or more, but will require occasional replacement of parts such as bearings, gears, chains, etc. Since these items may no longer be manufactured when they are needed, it will probably be more practical to custom make the items on demand than to attempt to hold stocks or to replace them with new units.

Architectural Tiles. Floor and wall panels and ceiling systems can be assumed both to rapidly become obsolescent and to require more than occasional replacement; therefore, reasonable stocks should be held so that uniformity of appearance can be maintained after spot repair and replacement.

Guideline 6-5 — Manual Methods of Inventorying

Several traditional methods of manual inventorying systems should be examined for use in controlling the supply of materials and parts.

Justification:

The checklist in Table 6-2 illustrates the multiplicity of items required by various maintenance and janitorial activities, and economy dictates that efficient record keeping be performed so that items in stock can be readily verified. For most items, a suitable system is one that uses a duplicate card index that describes each item and lists the allocated minimum and maximum quantities of stock. The stock on hand is maintained between these limits by recording withdrawals and by reordering when the minimum level is approached. Requisitions are written for materials and parts needed by the various work groups; one copy is kept at the warehouse and another is sent to the purchasing department. Both the warehouse and the purchasing office record withdrawals on their respective index card. In the warehouse, this card is often displayed on the bin or shelf and entries made as items are withdrawn or replaced.

This kind of a system enables the purchasing department to order items independently of the warehouse and the warehouse to rapidly check items on hand against their records.

Guideline 6-6 — Computerized Methods of Inventorying

Computerized systems of inventorying should be examined and compared with manual systems.

Justification:

An advantage of computerized inventory systems is the rapidity with which information can be obtained. Its basic function of providing information about stock on hand and reordering requirements can be expanded to study item demand patterns and to optimize desirable maximum and minimum stocks to be carried, thus effecting what may be appreciable cost savings. An additional advantage is the reduction in clerical labor required for inventory control. Many systems suitable for this application are available.

SUPPORT FACILITIES FOR MAINTENANCE OPERATIONS

The supporting facilities normally required by maintenance operations comprise, in the subway structures, storage rooms or areas for cleaning equipment and supplies and staff rooms and, on the surface, warehouses for materials and parts, garages and hard standings for trucks and other mobile equipment, and repair shops. Various building trades will also require shops, and the maintenance staff will need offices, change rooms, and lunch rooms. These latter facilities are often incorporated within the shops and warehouses which may be in compounds sharing space with comparable trades of other maintenance operations of the transit system.

Most existing transit properties have well established and satisfactory maintenance support facilities; therefore, the following guidelines may be superfluous in many respects, especially for properties that contract much of their maintenance work. However, the guidelines may be useful to properties considering modification of their present maintenance operations either because of expansion or because of changing from contracted to owner-provided services.

Guideline 6-7 — Station Facilities

Adequate storage space must be provided in a station to accommodate the types of cleaning operations performed there.

Justification:

Figure 6-1 shows typical facilities provided for cleaning a large subway station with space for the cleaning staff, trash collection, and some storage. A small elevator for the handicapped may be used to transport cleaning and maintenance equipment and supplies to street, mezzanine, and platform levels. This plan includes the minimum facilities required for efficient station maintenance; additional space would be required for mechanical floor cleaning equipment storage or for mechanical trash compaction and storage.

Guideline 6-8 — Building Trades Facilities

All of the provisions indicated in Figure 6-2 should be evaluated for their compatibility with the maintenance operation.

Justification:

Figure 6-2 shows a layout for shop and storage facilities required for the fixed mechanical equipment service vehicles and for the mobile cleaning equipment belonging to the building trades. The scheme is suitable

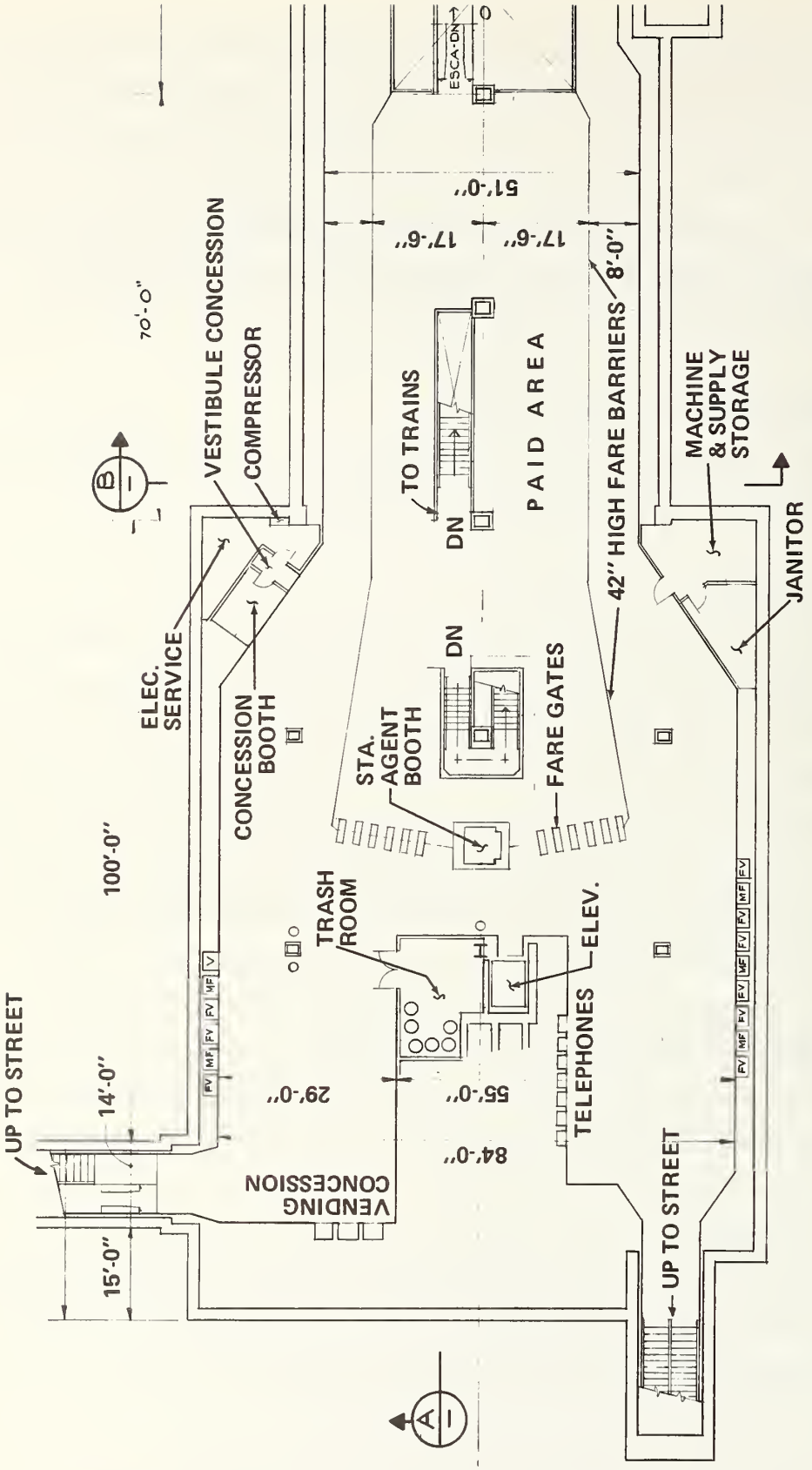
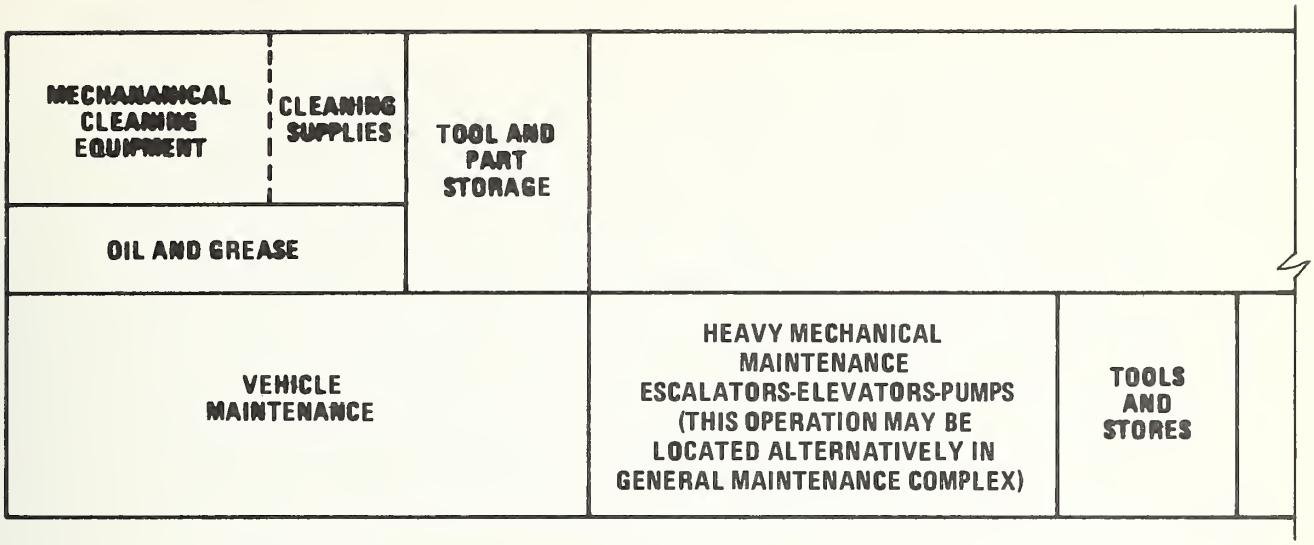


Figure 6-1. FLOOR PLAN OF STATION CLEANING FACILITIES



MAINTENANCE OF WAY – VEHICLE SHOP

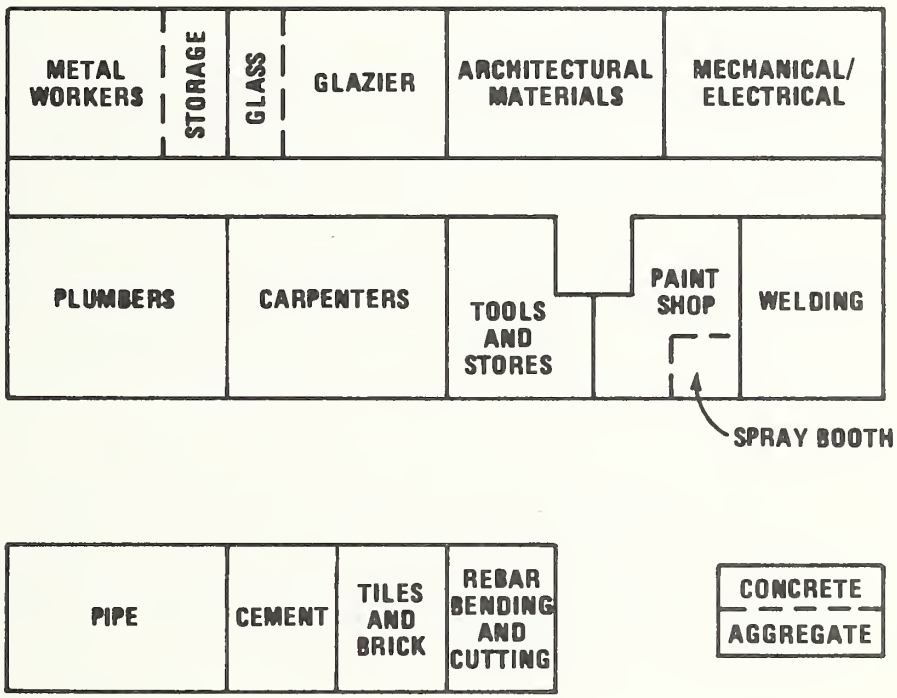


Figure 6-2. MAINTENANCE SHOP FACILITIES

for a property that performs its own maintenance, but even if much of the work were contracted some shop or storage space would still be required for the trades indicated. Offices, lunch rooms, change rooms, and other staff facilities are not shown; for direct line functions, these should be near the shops they relate to; for organizational or communal functions they may be located on other floor levels or in separate buildings.

Some of the fundamental requirements and relationships indicated are:

- The general building trades personnel should be close to their storage areas and tools.
- In many maintenance operations, labor from the various trade groups divides its time between the site and the shops; the same organizational structure can be used for both operations. Even where the field groups operate independently of the shop, it may still be convenient to have the base quarters of the field groups within this facility.
- For reasons of economy and transportation logistics to the sites of major use, bulk structural materials that generally require minimum covering and security may be stored away from the main service facility in centralized locations.
- Periodic overhaul of fixed mechanical equipment (such as escalators, elevators, and pumps) may be considered a heavy machine shop operation and may be conveniently performed in the machine shop for train vehicle maintenance, but this is not always necessary.
- Concurrently with planning the facility, necessary equipment and tools must be determined. This will generally require separate shops including those required for welding, painting (and paint spraying booths), wood and metal working equipment, pipe cutters, threaders, benders, etc. Mechanical and electrical shop, glazier, and servicing of vehicle cleaning equipment requirements must be included.

Section 7

SCHEDULING, TRANSPORTATION, AND ACCESS

Maintenance of the underground structure complex requires scheduling, transportation, and access; all of these factors are constrained by the types of maintenance involved, location of the items to be attended, and the schedule of revenue service. Additionally, this is only one of several kinds of maintenance operations that must be performed for the transit property, as shown in Figure 7-1.

The diagram shows the two major areas requiring maintenance are the trainway and the stations. The former is divided into four components: track, power, communications, and trainway structures. The station area includes vending machines and turnstiles, surveillance and public address, agent's booth control equipment, and station structures. Many items within the subway have parallel items in the at-grade portion of the trackway, but these are excluded from this report. The following guidelines are presented with these constraints and scope limitations.

SCHEDULING

Guideline 7-1 — Categorization of Maintenance Activities

Maintenance activities should be categorized according to three main locations: the trackway, the wayside facilities, and the stations.

Justification:

Revenue service operations affect maintenance scheduling differently in each of the three locations. Operations within the trackway are limited mainly to nonrevenue operating periods where 24-hour service is not

maintained. Wayside facilities include pumping, ventilation, and emergency exits and, because they have access from the surface or along the trackway service walkway, scheduling their maintenance is not greatly affected by train operations (except where track transport is involved). Scheduling station maintenance activities for floors, escalators, and elevators must take into account the passenger traffic flow. Other station maintenance activities may not be affected by passenger traffic.

Tables 7-1 and 7-2 show the impact of an item's location on the kinds of maintenance it may require. Table 7-1 covers trackway and wayside structures and uses a "yes, no, or partly" determination of whether location constrains various maintenance activities. It also indicates the probable track transportation requirements for an activity. Table 7-2 presents similar information for station structures. Track transportation will probably be required only for heavy structural repair which would require equipment such as track-mounted welding and compressed air equipment, cranes, etc.

Guideline 7-2 — Coordination of Maintenance Activities

Maintenance for underground structures must be scheduled in conjunction with other maintenance activities on the transit property. Various activities, especially those carried out in the trackway structure, may profit from interchanging equipment and labor among different maintenance groups.

Justification:

Certain maintenance activities lend themselves well to such an integrated approach. For example, track maintenance support equipment used for welding tools or compressed air tools can be used by structural maintenance groups. Track maintenance crews are often the logical unit to provide transportation for other maintenance groups and can also undertake some of the routine structure inspection. Replacement of tunnel

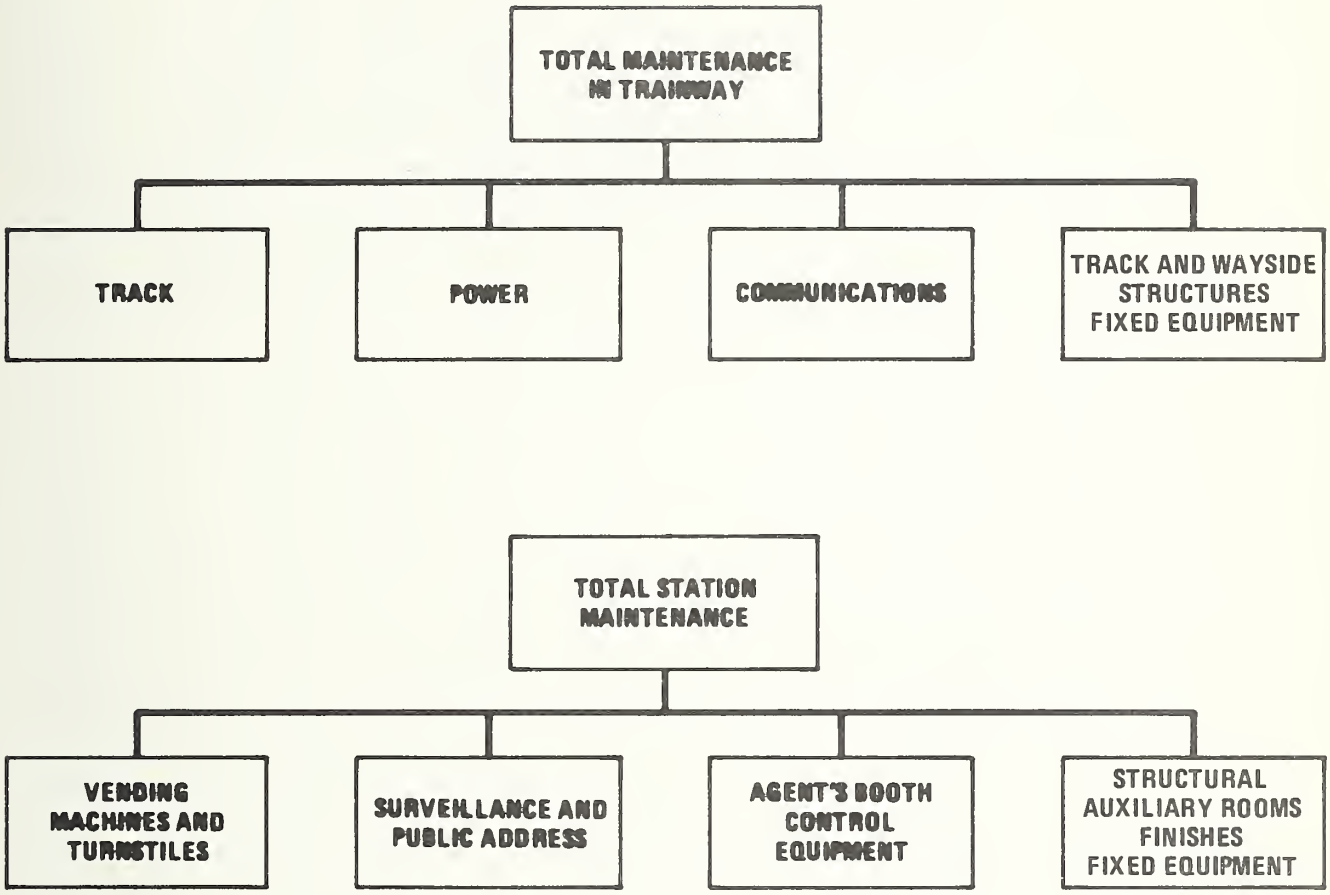


Figure 7-1. MAJOR COMPONENTS OF TOTAL MAINTENACE IN SUBWAY

Table 7-1

ACCESS TO MAINTENANCE ITEMS AS AFFECTED BY LOCATION
TRACKWAY AND WAYSIDE STRUCTURES

Maintenance Locations	Items	Inspection Maintenance	Scheduled Maintenance	Repair Overhaul	Clean	Items Requiring Track Transportation
Trackway	Structure	Y	Y (1)	Y (2)	Y (3)	1, 2, & 3 depending on extent of work
	Drainage system	Y	Y (1)	Y (2)	Y (3)	
Wayside structures	Pump structure	N	P (1)		P (2)	1 depending on extent and access; 2 for debris removal
	Pump equip-ment	N	N	Y/N (1)	N	1 depending on degree and access
	Vent structure	N	P (1)	P	P_2	1 for equipment and material transport; 2 for debris removal
	Vent equip-ment	N	N	Y/N (1)	N	1 depending on degree
	Emergency exits	N	P (1)	P (2)	P	1 & 2 depending on extent and access

Key

Y = Yes, access is affected
N = No effect
P = Partly affected

Table 7-2

ACCESS TO MAINTENANCE ITEMS
AS AFFECTED BY LOCATION – STATIONS

Location	Items	Repairs	Replacement	Inspection Maintenance	Routine Maintenance	Overhaul	Short-term Cleaning	Long-term Cleaning
Public Areas of Stations	Floors	N[a]	Y[b]	N	–	–	Y	Y
	Stairs	N	Y	N	–	–	Y	Y
	Walls	N	P[c]	N	–	–	Y	P
	Doors	N	N	N	–	–	Y	Y
	Glass & trim	P	P	N	–	–	N	P
	Ceilings	N	P	N	–	–	–	Y
	Lights	N	N	N	P	–	–	P
	Escalators	Y	Y	N	Y	N	Y	Y
	Elevators	Y	Y	N	Y	N	Y	Y
Nonpublic Areas of Stations	Floors	N	N/Y[d]	N	–	–	NY[d]	N
	Walls	N	N/Y	N	–	–	N/Y	N
	Doors	N	N/Y	N	–	–	N/Y	N
	Ceilings	N	N/Y	N	–	–	N/Y	N
	Lights	N	N/Y	N	N	–	–	N

(a) N = No effect
(b) Y = Yes, access is affected
(c) P = Partly effected
(d) Staff rooms only

lights, if on a burn-out schedule, can conveniently be done by the electronics maintenance group; if on a regular periodic schedule, this activity can be performed by the wayside mechanical equipment group.

In some areas, this approach may be countervened by union rules; however, if the rules are not restrictive, benefits can be gained by appropriate "trades crossing."

Guideline 7-3 — Detailed Maintenance Schedules

Schedules should be prepared on a weekly or monthly basis; samples are shown in Tables 7-3, 7-4, and 7-5. Table 7-3 lists some of the typical maintenance activities that might be required for a section of trackway. Data shown include location, activity, code, description of work, and the time and days when the work will be performed. All work is assumed to take place during nonrevenue or nonpeak service hours.

Table 7-4 shows similar information for wayside facilities. Access to items requiring maintenance is generally not restricted by train service, so maintenance can largely be performed during the daytime. Special situations may, however, require service from track maintenance vehicles and such work would have to be scheduled accordingly.

Table 7-5 shows typical station maintenance requirements. Some maintenance activities can be carried out while passengers are in the station and some must be scheduled for nonrevenue service periods.

The codes given to work activities are composed of two letters and a number. The first letter identifies the location of the maintenance area (T = track, F = facilities, and S = station), the second letter indicates the trade group responsible (S = structural, E = electrical, C = cleaning, etc.), and the two digit number represents a subtrade within the trades group (01 = concrete, 02 = civil work, 03 = plumbing, etc.).

Table 7-3

SCHEDULE AND DETAILS OF TRACKWAY MAINTENANCE

In Operation During Week Commencing _____
(Unless Stated Otherwise)

Line	Approx. Track Stationing (ft.)	Station	Code	Description of Work	Times	Days	Notes
#2	10 + 357		T-S-01	Grout cracked concrete	0030-	M-F	
	11 + 918		T-S-02	Repair steel vent support shaft #6	0030-0430	M-F	
	10 + 150 to 12 + 200		T-S-03	Inspect and clean drain catch basins	0030-0230	M	
			T-S-04	Paint trackway wall	0030-0530	M-F	
	10 + 150 to 12 + 200	Alpha	T-E-03	Relamp annual	1130 0330	Tu	
		Alpha	T-C-03	Clean trackway from station	0330-0530	M	
		Beta		Clean trackway from station		Tu	
		Delta		Clean trackway from station		W	
	10 700	#5	TC-04	Refuse pickup from pump-sumps	0020-0025	F	

Table 7-4

WAYSIDE FACILITY MAINTENANCE

Line	Approx. Track Stationing	Facility	Code	Description of Work	Times	Days	Notes
#2	11 + 918	Vent #6	FC-06	Inspection - Monthly	0900-1600	Tu-W	
			FM-07	Clean shaft - 6 months	0800-1000	F	
	11 + 918	Pump #6	FC-06	Inspection - 1 month	0800-1200	M	
		Pump #6	FM-07	Clean sump - 3 months	1000-1200	F	
	12 + 150	Emergency exit #6	F-S-04	Repaint steelwork (Periodic as determined)	0800-1500	T, W, Th	
		Emergency exit #6	F-M-06	Inspect door mechanism (1 month)	0800-1000	F	
		Emergency Exit #6	F-C-06	Clean - 3 months	0800-1700	F F	

Table 7-5

STATION MAINTENANCE

Location		Area	Description of Work				Notes
Line	Station		Code	Task	Times	Days	
#2	Alpha	Info Booth #2	S-S-05	Replace cracked gears	2330	Tu	
		Passageway #1	S-S-01	Cut out and repair floor tiles	0030	Tu	
		Col 25	S-S-01	Repair damaged metal	0900	W	
		Mezzanine	S-S-04	Change adverts	0930-1130	M	
		Refuse rooms #1 and #2	S-S-04	Repaint	0800-	M	
		Public areas	S-E-03	Relamp (annual)	0930-1500	Th	
		Escalators	S-M-01	Routine inspect	0800-1200		
		Elevators	S-M-01	Routine inspect	0800-1200		
		All floor areas	S-C-01	Short-term cleaning	2330-	M, T, W	
		Walls, public areas	S-C-02	Long-term cleaning	0900-	M, T, W	
		Escalator chambers	S-C-06	Routine cleaning	2330-0530	M, W, F	
		Elevator pits	S-C-06	Routine cleaning	2330-0130	M	

Guideline 7-4 — Overall Subway Structure Maintenance Schedules

Overall subway structure maintenance schedules should be developed from analysis of data gathered during inspection, and work priorities should be established; both tasks should be performed in concert with development of the detailed maintenance schedules discussed in Guideline 7-3.

Justification:

Data obtained during periodic inspections should be integrated with ongoing, routine maintenance so that the maintenance programs can be modified to increase effectiveness.

TRANSPORTATION

Maintenance requires transportation of men, equipment, and materials from the shops, stores, and depots to places of work. For light equipment and material, road vehicles usually suffice for stations and other facilities with surface access. Trackways and adjacent underground facilities can be maintained by on-track vehicles including work trains and, sometimes, revenue trains. Both of these forms of transportation can serve surface and aerial structures in the same manner.

In usual practice, separate surface vehicles are used for structure maintenance and for station cleaning, and the following guidelines assume properties old enough and large enough to need ongoing structure maintenance and refurbishing of architectural finishes.

Guideline 7-5 — Vehicle for Maintenance in Trackway

This vehicle should be equipped with compressed air to permit operation of pneumatic hammers, air tools, and paint sprayers; with electric power supply or generation for electric welding and hand tools; and with adjustable scaffolds to serve as working platforms. The vehicle may be either a road-rail type (capable of operating in either mode in which

case it would be diesel powered) or a track-only type. In the latter case, it could be powered by a diesel engine or from the track contact rail.

Justification:

Using self-equipped service vehicles for trackway maintenance permits maximum use of the often very short time available for work. The adjustable scaffolds provide safe and efficient working conditions. If the vehicle is diesel-powered (even with exhaust scrubbers), the trackway ventilation system must be operated, particularly when welding or spray painting is being done. If the vehicle is powered from the contact rail, timber or fiberglass shields must be provided.

Guideline 7-6 — Trackway Supply and Collection Vehicle

Vehicles or trains should be provided to transport equipment and materials to the trackway and to collect refuse and other materials for disposal.

Justification:

The basic vehicle is usually a flatbed with a power unit. A light crane or hoist may be installed for handling heavy items and for loading refuse into bins and unloading them at the point of disposal. Such work trains are probably required and used by all transit properties.

Guideline 7-7 — Inspection and Light Maintenance Vehicles

The use of such vehicles is recommended. A frequent selection is a 3/4-ton truck with hydraulically actuated auxiliary flanged wheels that permit operation on the trackway from any point of access.

Justification:

The vehicles can be used for many tasks including transporting inspection crews to the location to be inspected through the trackway and performing

maintenance work on pumps and ventilation equipment. The vehicles should be diesel powered with exhaust scrubbers; the alternative motive power would be propane.

Guideline 7-8 — Surface Vehicles for Structure and Architectural Finish Maintenance

Suitable vehicles should be equipped to support all structure and architectural finish maintenance activities in stations and other facilities with surface access. Some vehicles should be fitted with the necessary equipment and supplies for the trades involved — such as electrical, mechanical, and plumbing. Other vehicles should be properly equipped for painters, glaziers, woodworkers, and cement and tile workers.

Justification:

The vehicles described above are similar to what general building contractors use for the various trades involved. The compressed air and welding equipment would probably be supplied from mobile units trailing the maintenance vehicles, and the AC power for light hand tools would come from electrical outlets in the stations.

The numbers and sizes of vehicles will vary greatly among properties. Other determining factors are the distances between stations and the extent of contracted work.

Guideline 7-9 — Surface Vehicles for Cleaning

If a property undertakes its own cleaning, vehicles should be supplied to support the operation. They should be designed to transport labor crews, materials, and equipment from the depots to and between the stations. Hydraulic tail platforms would be satisfactory for carrying heavy equipment and supplies.

Justification:

The number of vehicles required depends on the organization of the cleaning and the degree of mechanization. With a fair amount of mechanization, the same group and its vehicles can clean two or three stations each night. With proper scheduling, the same vehicle might be used for transporting more than one cleaning crew.

The vehicles also can be used for long-term cleaning transport and, perhaps, for refuse collection.

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